TRANSFER OF TRAINING IN CHEMISTRY

A DISSERTATION

SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES OF THE JOHNS HOPKINS UNIVERSITY IN CONFORMITY WITH THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF EDUCATION

BY

EVELYN L. MUDGE

(Reprinted from "The Johns Hopkins University Studies in Education," Number 26)

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The experiment described in this volume is the result of the individual and cooperative efforts of a great number of people. Those who served as subjects were not acquainted with the purpose and import of the study. Without their help, however, this investigation would have been impossible. It is doubtful if any one of these subjects will ever read this volume, but should he do so it is hoped that he will feel that his contribution was worthwhile. To some five hundred high school, college and university students, who have given both time and effort, the writer is indebted. She is particularly indebted to those who secured the cooperation of these students: to Dr. Ellis C. Haworth, Head of the Science Department of the Schools of Washington, D. C.; to Dean S. B. Schofield of Western Maryland College; to Dr. Neil E. Gordon and to Dr. Florence E. Bamberger, both of The Johns Hopkins University. The writer is grateful to her colleagues in the Educational Seminar and to many other friends for criticisms and suggestions.

Throughout the progress of this study, a small group of experts and critics of research have given invaluable aid through criticism and advice. The writer is greatly indebted to the members of her advisory committee. Without in any way putting blame upon them for any portion of this volume which the reader may have occasion to question, the writer especially wishes to thank Dr. Florence E. Bamberger for her assistance in the clarification of the problem of this investigation and for her careful guidance throughout the progress of the study; Dr. J. M. Stephens for his penetrating criticism of experimental procedure and of statistical techniques; and Dr. E. E. Franklin for his specific suggestions as to source material.

EVELYN LELIA MUDGE.

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CHAPTER I

The Problem and Its Setting

I

General Summary of Experimental Work on Transfer of Training

The problem of transfer of training has been an important consideration in educational discussion for nearly two hundred years. Not until the development of statistical tools and experimental technique within the last thirty years, however, has its study advanced to the stage of objective investigation from which valid conclusions may be drawn. With the memory experiments of William James during the last decade of the nineteenth century, the solution of the problem of transfer passed from a period dominated by opinion to a period in which opinion began to be subjected to experimentation. The present tendency is to examine and compare the results of previous studies critically, to conduct further investigations for the purpose of extending and testing tentative conclusions, and to base final conclusions on the data thus accumulated.

At the present time there is a wealth of experimental data on the subject of transfer of training. Hollingworth[1] lists two types of studies in this field: (1) artificial laboratory experiments on limited tasks, and (2) experiments dealing with ability in the school subjects. Whether due to the complexity of the task, to the lack of time, to the inability of many classroom teachers to carry on experimentation, or for some other reasons, the latter type of experimentation under controlled conditions has been somewhat neglected. The study reported here lies in this field.

The solution of the problem of transfer requires the collation of numerous and varied experiments. It is necessary to assemble and examine the many studies in the field, to discover wherein there is agreement and to attempt to account

[1] Hollingworth, H. L., Educational Psychology, D. Appleton and Co., New York, 1933, Chapter XVIII.

for the similarity of results. It is also necessary to analyze the studies which show conflicting results, and thus from the whole mosaic to build up theories and explanations of transfer to be subjected to further experimentation and analysis. A beginning has just been made, to which the present study may serve as an additional link in the chain of evidence.

Experimental studies of transfer of training cover a wide and varied field, and the mass of data is so cumbersome that some means of organization must be adopted whereby studies dealing with the same phase of the general problem may be grouped together. The following scheme, based on the types of phenomena investigated, serves the purpose of this study. Representative studies of each type are given. No attempt is made to list all of the studies under the several headings, except classification number two, that of the transfer from theory to practice, in which division the present study belongs. The following outline presents the writer's classification of experimental studies of transfer and shows the relation of the present study to previous studies.

I. Memory experiments.

Ebert, E., and Meumann, E., Ueber Einige Grundfragen Psychologie der Uebungsphänomene im Bereiche des Gedächtnisses. Archiv für gesamte Psychologie, 1905, Vol. 4, pp. 1-232. Summary in Thorndike, Educational Psychology, 1913, Vol. II, pp. 369-376. Also Jordan, A. M., Educational Psychology, 1928, pp. 204-205. Effect of training in one type of memory work (nonsense syllables) upon other types of memory material (prose, poetry, nonsense syllables, numbers, words, letters, etc.).

Fracker, G. C., On the Transference of Training in Memory, Psychol. Rev., Monograph Supplement, 1908, no. 38, pp. 56-102. Effect of training in memory of order of sound intensities upon memorization of poetry, tones of gray, geometrical figures, etc.

James, William, Psychology, Vol. I, pp. 666-668, 1890. Effect of practice on one type of memory material (Paradise Lost) upon improvement in a similar type (V. Hugo's "Satyr").

Sleight, W. G., Memory and Formal Training, Brit. J. Psychol. 1911, Vol. 4, pp. 386-457. Effect of practice on three types of memory material (poetry, tables, prose) upon other types of material (dates and events, nonsense syllables, poetry, verbatim prose, gist prose, consonants).

Winch, W. H., The Transfer of Improvement in Memory in School Children, Brit. J. Psychol., 1906-1908, Vol. 2, pp. 284-293, 1909-1910, Vol. 3, pp. 386-405. Effect of practice in memorization of poetry upon the memorization of material from geography and history.

II. Transfer from theory to practice.[2]

Dorsey, M. F. and Hopkins, L. T., The Influence of Attitude Upon Transfer, J. Ed. Psychol., 1930, pp. 410-417. Transfer of knowledge of a subject and of knowledge of a method of study to their application to a specific situation.

Frutchey, F. P., Measuring the Ability to Apply Chemical Principles, Ed. Res. Bull., Dec. 13, 1933, Vol. 12, No. 10, pp. 255-260. Transfer from knowledge of chemical principles to the application of the principles.

Lehman, H. C., A Class Experiment in Transfer of Training, J. of Applied Psychology, Vol. 17, no. 1, 1933, pp. 77-82. Transfer from algebra (generalized arithmetic) to arithmetic.

Meredith, G. P., Consciousness of Method as a Means of Transfer of Training, Forum of Educ., 1927, Vol. 5, pp. 37-45. Transfer from the study of general science with and without the study of the essentials of a good definition to ability to formulate definitions.

Olander, H. T., Transfer of Learning in Simple Addition and Subtraction, Elem. Sch. J., 1931. Vol. 31, pp. 358-369, 427-437. Transfer of knowledge and skill gained in the study of certain addition and subtraction facts with and without generalization to other addition and subtraction facts not studied.

Scholchow and Judd, C. H. (Reported by Judd in The Relation of Special Training to General Intelligence, Ed. Rev., 1908, Vol. 36, pp. 28-42.) Transfer from knowledge of the principles of refraction to ability to hit a target at different depths under water.

Webb, H. A., Testing Laboratory Resourcefulness, Sch. Sci. and Math., March, 1922, Vol. 22, no. 3, pp. 259-267. Transfer from laboratory experience to laboratory resourcefulness.

Woodrow, H., The Effect of Type of Training Upon Transference, J. Ed. Psychol., 1927, Vol. 18, no. 3, pp. 159-172. Transfer from training in memorization with instruction in methods of memorizing to ability to memorize.

III. Cross education.

Bray, W. C., Transfer of Learning, J. Exper. Psychol., 1928, Vol. 11, no. 6, pp. 443-467. Transfer of skill in mirror target from right to left hand, and from hand to foot.

Ewart, P. H., Bilateral Transfer in Mirror Drawing, Ped. Sem. and J. Genet. Psychol., 1926, Vol. 33, pp. 235-249. Transfer from right to left hand in tracing star pattern in mirror.

Lashley, K. S., Studies of Cerebral Function in Learning—VI, Psychol. Rev., 1924, Vol. 31, 369-376. Transfer from right to left eye (rat) and from right to left hand (ape) paralyzing the resting member.

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[2] A detailed discussion of these studies, showing the relation to this study will be found on pages 5 to 8.

IV. Sensory discrimination.

Coover, J. E., Formal Discipline From the Standpoint of Experimental Psychology, Psychol. Mon., Psychol. Rev., 1916, Vol. 20, no. 3. Transfer from marking words to estimating weights. (See also Thorndike and Woodworth.)

Coover, J. E. and Angell, Frank, General Practice Effect of Special Exercise. Am. J. Psychol., 1907, Vol. 18, pp. 327-340. Transfer from discrimination of sound intensities to discrimination of shades of gray.

Judd, C. H., The Relation of Special Training to General Intelligence, Ed. Rev., 1908, Vol. 36, pp. 28-42. Transfer from practice in indicating the direction of one line upon accuracy in indicating the direction of other lines. Transfer of discrimination of geometrical figures with knowledge of results.

Kline, L. W., Some Experimental Evidence on the Doctrine of Formal Discipline, Bull. of State Normal School, Duluth, Minn., Feb., 1909. Transfer from cancellation of e's and t's to the cancellation of nouns, verbs, etc.

McKinney, F., Quantitative and Qualitative Essential Elements of Transfer, J. Exper. Psychol., 1933, Vol. 16, pp. 854-864. Effect of training in discrimination of geometrical figures upon discrimination of figures altered in symmetry and size.

McKinney, F., Identical Sensory Elements Versus Functional Equivalents in Visual Transfer Reactions, J. Genet. Psychol., 1932, Vol. 41, pp. 483-489. Effect of training in discrimination of one member of a pair of patterns upon discrimination of new pairs. (Rat)

Thorndike, E. L., and Woodworth, R. S., The Influence of Improvement in One Mental Function Upon the Efficiency of the Other Functions, Psychol. Rev., 1901, Vol. 8, pp. 247-261, 384-395, 553-564. Transfer from training in estimating areas of triangles, rectangles and circles ten to one hundred square centimeters, upon discrimination of similar figures twenty to ninety square centimeters, also upon estimation of lengths and widths. Effect of practice in cancellation of certain pairs of letters upon cancellation of other pairs.

V. Transfer from one school subject to other subjects or from one school task to another.

Briggs, T. H., Formal English Grammar as a Discipline, T. C. Record, 1913, Vol. 14, no. 4, pp. 1-93. Effect of intensive study of English grammar upon ability to see likenesses and differences, critically to test a definition, to apply a definition, to make a rule or a definition, to test reasons, to reason syllogistically, etc.

Broyler, C. R., Thorndike, E. L., and Woodyard, E., A Second Study of Mental Discipline in High School Studies, J. Ed. Psychol., 1927, Vol. 18, no. 6, pp. 377-404. Effect of certain school subjects or groups of subjects upon general mental alertness.

Coxe, W. W., The Influence of Latin on the Spelling of English Words, J. Ed. Res., 1923, Vol. 7, pp. 244-250, 1924, Vol. 9, pp. 223-233. Influence of the study of Latin upon the spelling of English words.

Curtis, F. D., Some Values Derived From Extensive Reading

of General Science, T. C. Contrib. to Ed., no. 163, 1924. Comparison of the influence of a course in general science and regular extensive reading upon knowledge and attitudes in science.

Eurich, A. C., Enlarging Vocabularies, J. Higher Ed., 1932, Vol. 3, pp. 315-317. Influence of vocabulary drill and reading on vocabulary.

Winch, W. H., The Transfer of Improvement in Reasoning in School Children, Brit. J. Psychol., 1922-1923, Vol. 13, pp. 370-381. Transfer from training in arithmetical reasoning to reasoning in general.

———, Accuracy in School Children. Does Improvement in Numerical Accuracy Transfer? J. Ed. Psychol., 1911, Vol. 2, pp. 262-271; 1910, Vol. 1, pp. 557-589. Transfer from arithmetical computation to arithmetical reasoning.

A more detailed examination of the experiments listed under the second heading is necessary to this study. All of these studies are similar in that they deal with transfer from general to specific factors.

Dorsey and Hopkins report evidence of positive transfer of knowledge, of a method of study, and of skill in reasoning to situations in which these three factors might be expected to operate. The authors found (1) that a group of Latin students made better scores on a vocabulary test consisting of words of Latin and of non-Latin origin when the students had been instructed to use their knowledge of Latin in answering the test questions (gains of experimental over control group were 9.6% for total score, 9.5% for old words, and 34.4% for new words); (2) that a group which had received instruction in methods of study made higher scores on a reading test consisting of uncontrolled reproduction and true-false questions than did a similar group which had not received such instruction; and (3) that a group which had just completed a course in descriptive geometry made higher scores on a reasoning test in which they were advised to use the skills which they had acquired in the course, than did a similar group which had not been given this advice. In each case, the experimenter pointed out the possibility of transfer to the experimental group, and in each case the experimental group was superior to the control group on the final test. These experiments differ from others which deal with the problem of transfer from Latin and mathematics in that the

possibility of transfer was pointed out to the subjects in an attempt to secure greater transfer through establishing "readiness." This study was included here because it deals with transfer from a general factor to a specific one, and because of the influence of the knowledge that transfer could be made. This latter may be thought of as transfer from theory to practice.

Although Frutchey's study is mainly an attempt to devise a means for measuring the ability to apply chemical principles, it is of interest here. As a method of testing the student's ability to apply chemical principles, the author compares the objective and the essay types of written examination upon which the students are to predict outcomes of situations and to state the principles involved. Since no measure of the student's knowledge of principles was secured other than a test of his ability to apply them, this is not a clear-cut study in transfer. The writer of the present study has attempted to measure both the knowledge of chemical principles and the ability to apply them.

In Lehman's experiment, students were given a series of numerical problems which could be solved by either arithmetical or algebraic methods. The problems ranged from those of simple arithmetical form to those of abstract algebraic form. The procedure was to note the method of solution used for each problem. The frequency of use of the algebraic method varied directly as the statement of the problem resembled algebraic form. Since no separate measure of ability with algebraic and arithmetical solutions was given, the training and test series were not differentiated. The training period took place before the experiment began. All conclusions were based on the data from the one set of problems.

Meredith's study yields evidence of transfer of training from the study of general science to ability to define ordinary words, only when the essentials of a good definition have been emphasized in formulating scientific definitions. Three groups of students studied the same subject matter (magnetism) by the same method, except that one group developed

definitions of important words and another group formulated the characteristics of a good definition and applied them to the definition of terms encountered during their study. The group which formulated its own criteria for making and judging a good definition reduced the number of errors made in defining ordinary words from thirty-one to twenty-two. The number of errors made by the group which had formulated definitions of scientific terms without a special study of the characteristics of a good definition increased from twenty-nine to thirty-five errors. The number of errors made by the third group increased from twenty-nine to thirty-two. This also is a study of transfer from theory to practice.

The study made by Olander is the only study in this group which does not yield evidence of transfer. Generalization of groups of arithmetical facts taught with addition and subtraction does not transfer to ability to handle other addition and subtraction facts.

The experiment of Scholchow and Judd is the most clear-cut type-study in this group. These authors found that skill in hitting a target immersed in water at different depths was increased by instruction in the principles of refraction. The investigation undertaken in the present study is a clear-cut study of transfer of training from theory to practice, in which the affecting (knowledge of chemistry) and the affected (ability to apply chemical knowledge) factors are differentiated. It most closely resembles the study of Scholchow and Judd in this respect. It differs from their study in that the two factors, knowledge of principles and the ability to apply them, are measured separately before and after the training period, and in that a greater number of principles are tested.

Webb found that laboratory resourcefulness was developed through laboratory experience. This experiment is unique in that the author used an actual laboratory test as a measure of laboratory resourcefulness. It differs from the present study in that no measure of knowledge of scientific principles was attempted, except as laboratory resourcefulness measures this knowledge. Here again the training and test series were not differentiated.

Woodrow's study differs from other studies of transfer in the field of memory in that instruction in methods of memorizing was given to the experimental group. In this sense it is a study of transfer from theory to practice. That definite transfer occurred, is shown by the greater gain (31%) made by the group which received instruction in how to memorize.

The results of the above studies indicate that there is some transfer from knowledge to its application, or from theory to practice. Little can be said at present as to the extent or amount of such transfer, but the fact that there is some transfer is of importance in the field of education.

A great number of studies is concerned with the problem of transfer of training as a pyschological phenomenon; while, on the other hand, a relatively small number is concerned with the theoretical explanation of how and why transfer occurs. This investigation falls in the former class. No attempt is made to explain the results in terms of any particular theory of transfer.

II

The Problem

The present study is an attempt to determine the extent to which knowledge of chemistry, as taught in the classroom and laboratory in high schools, transfers to the solution of everyday problems of a chemical nature. Courses of study [3] indicate at least two ways in which chemistry may be expected to transfer to daily life: (1) in the application of chemical information to the solution of everyday problems of home and shop, and (2) in ability to read intelligently popular scientific and quasi-scientific literature. These are, however, only two of the several basic aims of the teaching of chemistry in high schools. Text-books [4] and articles dealing with the teaching of science cite these among the more important values to be derived from a course in chemistry and, on these grounds, partly justify its place in the curriculum.

[3] Appendix B, part 1 gives a list of objectives obtained from this source.

[4] Appendix B, part 2 gives a list of values of high school chemistry obtained from science methods text-books and magazines.

The problem of transfer from theory to practice is vitally related to the teaching of high school chemistry. First, it is necessary to find the extent to which transfer does take place under existing curricula and current methods of instruction. Are children who have had a course in chemistry in high school better able to solve problems in home and shop? Are they better able to interpret intelligently scientific literature than are children who have not studied chemistry? Can they solve problems and can they read more intelligently scientific material three or four years after they have had a course in chemistry than can those pupils who have not had such a course? The purpose of this study is to find answers to these questions.

It is not the writer's purpose to evaluate these two aims of the teaching of chemistry in high school or to evaluate or to measure any other aims. Neither is it an attempt to appraise the quality of instruction in the field of chemistry in secondary schools. This is an objective study of two aims selected from among several because of the writer's particular interest in them. For evidence of the need of adequate science background as preparation for the reading of popular scientific literature, the reader is referred to a study of the values of extensive reading in general science, made by F. D. Curtis.[5]

If the evidence in this study had pointed to the fact that there was no transfer or only a slight amount, a second problem would have been how to secure or to increase it. This phase of the research lies outside the scope of the present study. In Chapter IV are listed a number of related problems for subsequent investigation.

The present study yields evidence of significant temporary transfer from theory to practice in the field of chemistry at the high-school level. It furnishes another link in the chain of evidence of transfer in a limited field, from which eventually general conclusions concerning transfer from theory to practice may be drawn as more evidence accumulates.

[5] Curtis, F. D., Some Values Derived from Extensive Reading of General Science, Teachers College Contributions to Education, Columbia University, No. 163, 1924.

CHAPTER II

Preliminary Procedures

General Plan

The general problem was to find out if a year of chemistry in high school produces any gain in (1) knowledge of chemistry, and (2) ability to apply this knowledge to the solution of everyday problems involving chemistry, and to the intelligent understanding of popular scientific writings. To determine this, scores on written tests administered to equated experimental and control groups were obtained at the beginning and the end of the year. The experimental group consisted of a group of students who were just beginning the study of chemistry in high school. The control group consisted of a group of pupils equivalent to the experimental group in intelligence, knowledge of chemistry, and ability to apply chemical knowledge. This group was not beginning the study of chemistry. Two types of tests were required: one to measure the amount of chemical information, and one to test the ability to apply it. The Iowa Placement Examination Chemistry Training Tests, Forms A and B, were selected as a measure of chemical information. These tests have a reliability coefficient of .92. Scores on these tests have a correlation coefficient of +.65 with grades in college chemistry. Hereafter these will be referred to as the Iowa A and B or as training tests. To measure the ability to apply chemical knowledge a test had to be constructed, since no adequate one was available. The construction and validation of this test is discussed on pages 10 to 13. The reliability coefficient is .89. A copy of the test in the final form as used in this study is found in Appendix D. Hereafter this test will be referred to as the functional test.

Construction of the Functional Test

The actual construction of the functional test began in 1931. Part One, consisting of a series of verbal descriptions

of situations in which the average person might find himself, was drafted from questions prepared in previous years for high school students of chemistry. The majority of the items had been suggested to the writer by questions asked by students in the classroom and laboratory. To these were added new questions. Sample situations from Part One are given below.

Part One. Directions: Below are described some situations which may occur in everyday life. Many of them do. Read the statement of each situation carefully. Place the number of each solution which you consider effective in the column marked +. Place the number of each phrase which you consider not effective or dangerous in the column marked —. Each number should go in one of the columns, but no number may go in both.

		+	—
1. A gas range smokes. If the following attempts at correction were made, which would be successful? (+) Unsuccessful? (—) (1) turn the burner lower, (2) increase the amount of air in the mixture, (3) decrease the amount of air in the mixture.	1	.....	.....
2. A piece of material is advertised as all wool. Which of the following would test the purity of a small sample of it? (+) Which would not? (—) (1) household ammonia, (2) vinegar, (3) alcohol, (4) lye, (5) carbolic acid.	2	.....	.....
3. If you spilled tincture of iodine on an unstarched white cloth, which of the following would completely remove the stain? (+) Which would not remove it completely? (—) (1) soda, (2) alcohol, (3) vinegar, (4) water.	3	.....	.....

Part two, which attempts to determine the ability of pupils to apply chemical knowledge to the intelligent interpretation of popular scientific literature, was prepared from books selected from a chemistry reading list issued by the American Association for the Advancement of Science. This list contains a number of titles of books of a popular nature recommended for the non-technical reader. The writer chose three books from this list, selected a number of excerpts, and

formulated a series of questions to test the student's understanding of the selected passages. See appendix for complete test.

As a preparatory measure, the complete test, together with the manual of directions, was tried out on several adults individually, and on one class studying chemistry in high school. This trial form was revised and given to twenty-five high school students who were studying chemistry. A study of the results of this tryout revealed the necessity for changes in (1) the manual of directions, (2) the wording of many of the statements, (3) the order of arrangement of the questions, and (4) the manner in which the responses were to be indicated and scored. All of these revisions are incorporated in the final copyrighted form used in this investigation for both the initial and the final testing.

The scoring of these tests involved several interesting problems. Since it is conceded that applied knowledge concerns itself not only with knowing what reagents to use, but also which to avoid, it was thought best to score as right each item which was correctly chosen as useful or correctly labelled as useless or dangerous. In Part One the students marked each choice with a plus or minus, omitting none. In Part Two the students checked only the correct solutions, therefore omissions which were in accord with the key were scored as right. All others were scored as wrong. The system of scoring recommended by the Coöperative Test Service was used. To secure accuracy of results, each paper was scored by one scorer and checked by another scorer. As an additional guarantee of accuracy, one-tenth of the papers were rechecked by a third scorer.

For the purpose of establishing reliability, the scores of ninety-eight high school students on the odd and even questions of the test were correlated, giving a correlation coefficient of .81. The data are given in Table I. By the Spearman-Brown formula for the reliability of a lengthened test, a coefficient of .89 is obtained. The validity of Part One of the test is yet to be determined by a comparison of the scores on the written test with scores on a laboratory test involving many of the same situations.

TABLE I

CORRELATION OF SCORES ON ODD AND EVEN QUESTIONS ON FUNCTIONAL TEST

		Odds													
		10	15	20	25	30	35	40	45	50	55	60	65	70	fy
Evens	10-14		1												1
	15-19	2		7	1	1	3								14
	20-24		1	5	6	8	7	4	1	1					33
	25-29				1	3	2	6	4	1					17
	30-34					1	4	3	5	4	1				18
	35-39							1	1		2			1	5
	40-44							3	2	2		1			8
	45-49							1		1					2
fx		2	2	12	8	13	16	18	13	9	3	1	1		98

$r = .809 \pm .023$

Supplementary Information

To discover if there were forces other than classroom and laboratory instruction which might affect the test scores, questionnaires were drafted including such items as science club membership, science magazines read, previous courses in science, and scientific lectures and films attended. After a study of the answers given by fifteen high school students by whom the trial questionnaire was returned, the questionnaire was revised. The final form as used in this study is found in Appendix D.

Subjects Used

For the major part of this study the test scores of students in grades ten, eleven, and twelve in one of the large high schools in Washington, D. C., were used. More than half of these students were studying chemistry. Of the remainder, only those who had never studied chemistry were used. These will be referred to in Chapter III as the immediate-transfer control and experimental groups. The numbers and grade distributions of the groups finally selected for experimental purposes are shown below.

TABLE II

GRADE DISTRIBUTION OF HIGH SCHOOL GROUPS

Grade	Chemistry Group (Experimental) Number	Non-Chemistry Group (Control) Number
10	35	10
11	12	27
12	5	4
Total	52	41

Permanence of Transfer

The question of what residue of factual and functional information persists after an interval of from one to four years since taking chemistry constituted a second problem. Students from Western Maryland College were subjects for this part of the study. Some had taken chemistry in high school and some had not taken it. None was studying or had studied chemistry in college. These students were divided into two groups, referred to in Chapter III as "residual-transfer experimental group" and "residual-transfer control group." These groups were tested at the beginning and at the end of the college freshman year by means of the same tests as were given to the high school groups. It was thought that a comparison of the scores of the college freshmen with the scores of the high school students would give some indication of the residue of chemical and functional information, while a comparison of the initial and final scores of the college experimental and control groups would give some indication of the rate of forgetting.

In equating the college groups, it was assumed that they were also equivalent while in high school. While it is probably true that the two groups were as much alike three years before as at the time of the equating, it is possible to conceive of them as being less alike in some or in all traits. If they were less alike in the traits related to ability to master and apply the facts of chemistry, then it is a questionable procedure to compare the two groups at this later time. It

is possible to conceive of two groups now equivalent in intelligence (Thurstone scores) to have been quite different some years before. It is also possible that the groups may have been equivalent in intelligence at both times, but may have differed in other important traits, such as special interest in chemistry, which might affect achievement on the tests used here. Thus, while in high school the two groups may have differed in intelligence or in interest in chemistry or in both, and still not reveal these differences at a later date. To check this assumption, a study of the influence of choice of chemistry upon subsequent scores, as well as a study of the relation of choice of chemistry to intelligence had to be made. For this purpose, four groups of students from The Johns Hopkins University and Western Maryland College were selected on the basis of answers to questionnaires which were designed to discover which students elected or avoided chemistry and which students had no opportunity to elect it. The groups as finally selected may be characterized as follows:

Group one—students who chose to take chemistry in high school; hereafter referred to in this study as the " chemistry-choice group."

Group two—students who took chemistry in high school because it was a required course; hereafter referred to in this study as the " chemistry-no-choice group."

Group three—students who elected not to take chemistry in high school; hereafter referred to in this study as the " no-chemistry-choice group."

Group four—students who were not given any opportunity to take chemistry in high school; hereafter referred to in this study as " no-chemistry-no-choice group."

All four groups took the functional test and Form A of the training test. The scores of each group were examined to find out if the factor of choice influenced subsequent achievement in chemistry. Upon the findings of this supplementary study rests the validity of the assumption that equivalent groups in college were also equivalent groups while in high school.

Summary

The general plan of procedure for the high school groups may be summarized as follows:

1. Equating factors	Mental age, initial scores on training and functional tests. Both groups.
2. Pretests	Iowa Training Test, Form A; functional test. Both groups.
3. Training	Experimental group: one-year course in chemistry in high school. Control group: no chemistry course.
4. Final tests	Iowa Training Test, Form B; functional test, same form as pretest. Both groups.

The plan of precedure used to determine the residue of factual and functional information after one to four years have passed may be summarized as follows:

1. Equating factors	Thurstone scores, scores on first training and functional tests given to both groups at beginning of freshman year in college.
2. Pretests	None. The functional and training tests were not administered to the students of either group while in high school. First tests were given in freshman year at college and groups were equated at that time, assuming that they were also equivalent when in high school. (See 4 below.)
3. Training period	Occurred for the experimental group before first tests were administered. No training period for control group.
4. First tests	Iowa Training Test, Form A; Functional test, single form. Tests administered to both groups at beginning of experiment, but not before the training period.
5. Measure of further loss: final tests	Iowa Training Test, Form B; functional test, single form. Administered one year after first tests.

CHAPTER III

Final Procedure and Results

I. Immediate Transfer

A. Selection and equating of the groups. High school students in grades ten, eleven, and twelve served as subjects to determine the amount of immediate transfer from knowledge of chemistry to the application of this knowledge to daily problems and to the interpretation of scientific literature. They were divided into two roughly comparable groups: (1) a chemistry or experimental group just beginning a course in chemistry, and (2) a non-chemistry or control group not taking chemistry.

In September, 1932, both groups took the Iowa Training Test Form A and the functional tests. On the basis of these test scores and of the intelligence records obtained from the school, the groups were equated on mental age, knowledge of chemistry, and ability to apply chemical information. Tables III through V give the status of both groups in these factors at the beginning of the experiment. Tables VI and VII give the intelligence quotient and chronological age of the two groups. The tables include only the data for the cases finally used in this part of the study.

TABLE III

MENTAL AGE OF HIGH SCHOOL GROUPS

M. A.[1] Months	Chemistry Group (Experimental)	Non-Chemistry Group (Control)
225-229	3	1
220-224	2	2
215-219	1	2
210-214	3	3
205-209	4	4
200-204	12	4
195-199	5	6
190-194	8	6
185-189	3	4
180-184	6	5
175-179	1	1
170-174	1	2
165-169	2	1
160-164	1	0
Total	52	41
Mean	197.10 ± 1.39	196.51 ± 1.50
S. D.	14.95 ± 0.98	14.25 ± 1.06

TABLE IV

INITIAL SCORES OF HIGH SCHOOL GROUPS ON TRAINING TEST

Score A	Chemistry Group	Non-Chemistry Group
27-29	1	2
24-26	2	2
21-23	4	2
18-20	5	3
15-17	5	5
12-14	6	3
9-11	4	8
6- 8	9	3
3- 5	9	6
0- 2	7	7
Total	52	41
Mean	10.86 ± .70	11.17 ± .84
S. D.	7.50 ± .49	7.95 ± .59

[1] These M. A.'s have been calculated from I. Q.'s which had been obtained from intelligence tests given one to three years earlier. In calculating I. Q.'s, chronological ages above 16 were disregarded.

TABLE V

INITIAL SCORES OF HIGH SCHOOL GROUPS ON FUNCTIONAL TEST

Score	Chemistry Group	Non-Chemistry Group
65-69	0	1
60-64	0	0
55-59	4	0
50-54	3	2
45-49	4	6
40-44	6	4
35-39	12	14
30-34	5	3
25-29	10	5
20-24	5	3
15-19	3	3
Total	52	41
Mean	36.04 ± 1.02	36.27 ± 1.10
S. D.	10.90 ± .72	10.45 ± .78

TABLE VI

INTELLIGENCE QUOTIENTS OF HIGH SCHOOL GROUPS

I. Q.	Chemistry Group	Non-Chemistry Group
135-139	1	0
130-134	0	1
125-129	2	0
120-124	3	2
115-119	9	3
110-114	12	5
105-109	9	6
100-104	3	11
95- 99	9	7
90- 94	1	4
85- 89	3	1
80- 84	0	1
Total	52	41
Mean	108.63 ± .99	104.07 ± 1.04
S. D.	10.60 ± .70	9.90 ± .74

TABLE VII

CHRONOLOGICAL AGE OF HIGH SCHOOL GROUPS

Months	Chemistry Group	Non-Chemistry Group
233-239	1	0
226-232	0	2
219-225	0	0
212-218	3	4
205-211	2	0
198-204	3	7
191-197	9	19
184-190	9	3
177-183	9	2
170-176	7	1
163-169	7	3
156-162	1	0
149-155	1	0
Total	52	41
Mean	185.25 ± 1.50	195.20 ± 1.45
S. D.	16.03 ± 1.06	13.79 ± 1.03

An examination of Tables III through VII shows the two groups to be practically equivalent in mental age, initial score on the training test, and initial score on the functional test. The experimental group exceeds the control group in intelligence quotient by 4.56 ± 1.44 points. The control group averages 9.95 ± 2.09 months older chronologically than the experimental group. Being a function of age, the grade distributions (Table II, Chapter II) also are not comparable for the two groups. If the difference in chronological age is significant and shows the experimental group to be younger, and if at the same time the difference in intelligence quotient is in favor of the experimental group, it is clear that both factors would operate to make the test gains for this group appear to be larger than they really are. The correlation of each of these factors with gains on both the functional and the training test corroborates this statement. The correlation coefficients of intelligence and gains on both tests are positive. (r training gains. I.Q. = + .38 ± .06, and r func-

tional gains. I.Q. = +. 20 ± .07) The correlation coefficients of chronological age and gains on the two tests are negative. (r training gains. C.A. = — .37 ± .07, and r functional gains. C.A. = — .14 ± .07) The correlation coefficients were calculated from the records of eighty high school students who were just completing a course in chemistry. The correlation tables are given in Appendix C. Since the difference in the intelligence quotients of the two groups is small, and since the correlation between test gains and intelligence quotient is not high, the difference may be disregarded. This leaves the chronological age as the only significant difference which is shown by these data at the beginning of the experiment.

To secure information concerning the science background of these students, both groups answered the questionnaire referred to on page 13. The original plan to use the results of the questionnaire in equating the groups had to be abandoned because it entailed the loss of too many cases. There were no significant differences between the two groups in the number of scientific magazines which they had read, or in the number of extra-school lectures in science which they had attended. As regards the number and variety of courses which these students had taken before the beginning of the experiment, the science background of the two groups is not the same. The data showing the science background of both groups are found in Appendix C.

B. Training period and final testing. In June, 1933, both groups took Form B of the Iowa Training Test and the single form of the functional test. Between the initial and final testing, the experimental group took a course in chemistry. The control group had not taken such a course before and did not do so during this time. Tables VIII and IX give the final scores on the two tests for both groups.

TABLE VIII

FINAL TRAINING TEST SCORES FOR HIGH SCHOOL GROUPS

Score	Chemistry Group	Non-Chemistry Group
112-118	1	
105-111	3	
98-104	4	
91- 97	0	
84- 90	3	
77- 83	3	
70- 76	3	
63- 69	6	
56- 62	9	
49- 55	5	1
42- 48	5	0
35- 41	6	0
28- 34	0	3
21- 27	2	4
14- 20	1	9
7- 13	1	13
0- 6	0	11
Total	52	41
Mean	63.04 ± 2.27	13.59 ± 1.08
S. D.	24.64 ± 1.59	10.29 ± .76

TABLE IX

FINAL FUNCTIONAL TEST SCORES FOR HIGH SCHOOL GROUPS

Score	Chemistry Group	Non-Chemistry Group
98-104	2	
91- 97	1	
84- 90	4	
77- 83	4	
70- 76	8	
63- 69	6	1
56- 62	10	2
49- 55	7	6
42- 48	4	13
35- 41	5	10
28- 34	0	4
21- 27	1	5
Total	52	41
Mean	63.31 ± 1.24	41.58 ± 1.05
S. D.	13.29 ± .88	10.01 ± .74

C. Results for the high school groups. Table X presents in summary form the data given in Tables III through IX.

TABLE X

SUMMARY OF DATA FOR HIGH SCHOOL GROUPS

Trait		Chemistry Group (Experimental)	Non-Chemistry Group (Control)	Difference in favor of Exp. Group
I. Q.	Mean	108.6 ± 0.99	104.1 ± 1.04	4.5 ± 1.44
	S. D.	10.6 ± 0.70	9.9 ± 0.74	0.7 ± 1.02
M. A.	Mean	197.1 ± 1.39	196.5 ± 1.50	0.6 ± 2.04
	S. D.	14.9 ± 0.98	14.2 ± 1.06	0.7 ± 1.44
C. A.	Mean	185.2 ± 1.50	195.2 ± 1.45	—10.0 ± 2.09
	S. D.	16.0 ± 1.06	13.8 ± 1.03	2.2 ± 1.48
Final Training Test	Mean	63.0 ± 2.27	13.6 ± 1.08	
	S. D.	24.6 ± 1.59	10.3 ± 0.76	
Initial Training Test	Mean	10.9 ± 0.70	11.2 ± 0.84	—0.2 ± 1.10
	S. D.	7.5 ± 0.49	7.9 ± 0.59	—0.4 ± 0.77
Final Functional Test	Mean	63.3 ± 1.24	41.6 ± 1.05	
	S. D.	13.3 ± 0.88	10.0 ± 0.74	
Initial Functional Test	Mean	36.0 ± 1.02	36.3 ± 1.10	—0.3 ± 1.50
	S. D.	10.9 ± 0.72	10.4 ± 0.78	0.5 ± 1.05
Gain on Training Test		52.2 ± 2.26	2.4 ± 0.83	49.8 ± 2.41
Gain on Functional Test		27.3 ± 1.12	5.3 ± 1.08	22.0 ± 1.56

Examination of Table X shows the following:

1. The group studying chemistry for one year gained 52.2 ± 2.26 points on the training test and 27.3 ± 1.12 points on the functional test.
2. Over the same period, an equivalent group not studying chemistry gained 2.4 ± 0.83 points on the training test and 5.3 ± 1.08 points on the functional test. These gains, however, are small and perhaps can be attributed to the practice effect of the tests.
3. Measured by raw scores, the experimental group made greater gains on both tests than did the control group.
4. For both groups there is an increase in the mean and the spread of the scores on the training test, but the increase is greater for the group studying chemistry. For the experimental group, there is an increase in the

mean and spread of scores on the functional test. For the control group, there is an increase in the mean and a negligible decrease in the spread of scores.

5. Measured in terms of raw scores, the chemistry group gained over twenty times as much as the control group gained on the training test, and five times as much as the control group gained on the functional test.

An examination of the above summary for evidence of transfer shows that, according to the first statement, the experimental group gained more points on the training than on the functional test. What is meant by point gains? Does a gain of fifty-two really represent a greater growth than a gain of twenty-seven, and if so, how much greater? The answer to these questions would depend upon whether or not a unit or point on one test is equivalent to, or is as hard to acquire as a unit on the other. A point gain, which is the unit of measurement here used, is not a standard fixed quantity like a pound or a foot, hence a gain of one point on one test may not be equivalent to a gain of one point on the other. If we were to assume that they are equivalent, we could say that there is about fifty-one percent transfer. If, however, we were to assume that a gain of one point on the training test is equivalent to a gain of two points on the functional test, then the amount of transfer would be twenty-six per cent. Likewise, if we were to assume that a gain of one point on the training test is equivalent to a gain of half a point on the functional test, then the amount of transfer would become ninety percent. Thus, it is evident that whether the gains of fifty-two and twenty-seven indicate large or small growth depends upon the equivalence of the units.

According to the second statement, the control group gained more points on the functional than on the training test. The equivalence of the point gains here need not be considered, since the gains are small, and the percent of transfer is calculated from the gains made by the experimental group.

The comparisons involving the scores made on either test by two different groups are not subject to the difficulty of the non-equivalence of the point gains. Thus, all comparisons of scores made by the experimental and control groups may be read directly from Table X.

The problem, then, resolves itself into that of determining the equivalence of the units of gain on the two different tests in order to calculate the percent of the training gain which actually transfers to functional gains. Stated in simpler terms, it involves securing an answer to these questions: What does a raw score gain of twenty-seven points on the functional test mean when compared with a gain of fifty-two points on the training test? Does it represent any significant amount of transfer? To find a quantitative answer to these questions, three techniques were applied: (1) correlation coefficient, (2) partial correlation, and (3) standard scores. These will be discussed in the following pages of Section One of this chapter.

Before applying these three measures to the data of this study, it will be well to illustrate two of them in a simpler setting where the advantages and limitations of each may be more apparent. An imaginary problem with somewhat exaggerated data will serve best.

Let us suppose that the raw data from an experimental study indicate that as one increases in weight one is able to throw a basket ball a greater distance. We wish to know how much of the gain in weight transfers to skill in throwing the ball. By correlating the gains in the two traits, we obtain a coefficient of $+ .80 \pm .04$. What does this tell about the amount of transfer which occurs? It tells first that, in general, a gain in weight is accompanied by an improvement in throwing a basket ball for distance. It tells also that, in general, the larger gains in distance accompany the greater gains in weight. Judging by the coefficient only, we should be inclined to think that the amount of transfer is truly significant. We may even predict that a gain of fifteen pounds in weight will probably be accompanied by a gain of

six inches in throwing the ball.[1] It does not show whether six inches is a good gain or is even significant in comparison with the gain in weight. It does not suggest what proportion of the gain in weight actually transfers to ability to throw a ball a greater distance. It shows only the extent to which the gains tend to vary concomitantly and the point gains which might be expected on either test for a given gain on the other.

Let us, then, suppose that the coefficient of correlation is + 1.00. This means that if the subjects were arranged in descending order according to the gains made in one trait, the order would be the same for the other trait. The person who made the greatest gain in weight would also make the largest gain in distance. The same would be true throughout the entire range of the gains in the two traits. But a coefficient of + 1.00 does not indicate that any specific proportion of the gain in one trait transfers to the other. The amount of transfer can be negligible even with perfect correlation.

How may we determine whether a gain of fifteen pounds or of six inches is significant? A number is not inherently large or small; it is large or small only in comparison with other numbers in the same category. Over a limited time, fifteen pounds, no doubt, would be considered a great gain in weight. Considering that the distance which an individual may throw a basket ball on three successive trials may vary by as much as two or three feet, a gain of six inches is relatively insignificant. If a great gain in weight is accompanied by only a slight gain in distance, the amount of actual transfer is small. It is obvious, then, that the correlation coefficient is not an adequate single measure of transfer, since a high correlation may exist between traits which show only a small proportion of transfer from one to the other.

The fact that a comparison of given gains with expected gains determines whether the gains are large or small suggests a comparable unit of measurement. For every distribution

[1] With σ weight = 6.4, σ distance = 2, and r weight-distance = + .80 ± .04; weight in pounds and distance in inches.

of traits for a large unselected group, there is a rather wide range or spread of scores. Since the range of scores in different traits varies widely, a quantitative statement of the range does not give an adequate picture of the variability of the group in any one trait and does not afford a basis for comparison of the variabilities of two or more groups. The standard deviation is the most stable measure of variability and may be used to convert raw scores or raw score gains into comparable terms. A gain of one standard deviation on one test is comparable to a gain of one standard deviation on any other test. Thus, a gain of one S.D. on each of two tests of different traits represents one hundred percent transfer. A gain of one standard deviation in one trait and of .5 S.D. in another trait represents fifty percent transfer.

Using this more accurate procedure, let us return to the example of the relation of weight to ability to throw a ball, and test the conclusion stated there: namely, that the amount of transfer is negligible despite the high correlation coefficient. The comparability of the standard deviations of the two different traits depends upon whether there is a normal distribution of the traits in the group from which the standard deviations are obtained. Therefore, if the standard deviations are used as units, they must be computed for the whole population or for a typical sample of it in which the traits are distributed normally. If the standard deviation of the gain in weight for a sampling of the whole population is 7.5 and the standard deviation of the gain in distance of throw is 12, the raw score gains for any group, large or small, divided by these numbers will convert the gains into standard deviation (equivalent) units. A gain of fifteen pounds, then, is 15/7.5 or 2 S.D. A gain of six inches is a gain of .5 S.D. This represents only 25 percent transfer. The bearing of this upon the present study is obvious. Whether the functional gains are large or small in comparison with the training gains depends upon the variability in these two traits of high school students of chemistry in general.

If we apply similar techniques to the data of this investiga-

tion, it will be necessary to keep in mind the following facts: (1) that the coefficient of correlation is an accurate measure of the tendency of the two gains to vary concomitantly, but not of the percent of the gain in one trait which transfers to the other, and (2) that raw point gains in the two traits are not comparable. Each must be reduced to standard score gains by dividing the raw gains by the standard deviation of the gains made on that test by a typical sample of all students taking high school chemistry. These standard score gains are comparable and can be used to calculate the percent of transfer.

Correlation of the Gains of the Two Tests as a Measure of Transfer

The first measure of the amount of transfer which occurs from knowledge of chemistry to its application is a correlation of the gains made by the experimental group on the functional and training tests. Table XI, which gives these correlation data, shows the extent to which an increase in score on one test is accompanied by an increase in score on the other.

TABLE XI

CORRELATION OF GAINS ON TRAINING AND FUNCTIONAL TESTS
High School Experimental Group

Gains on Functional Test	Gains on Training Test													
	0	10	20	30	40	50	60	70	80	90	100	110	120	fy
0- 4				2										2
5- 9			2	1				1						4
10-14	1		1				2							4
15-19		1	1		4	1	1							8
20-24					2					1				3
25-29				1	1		3	1						6
30-34				2	2	1					1			6
35-39			2		2		1			1	1			7
40-44				3						1				4
45-49						2	1	2			1	1		7
50-54														0
55-59							1							1
fx	1	1	6	9	11	6	8	3	1	2	3	1		52

$r = .45 \pm .074$

$Mx = 52.58$ $\sigma x = 24.49$
$My = 27.87$ $\sigma y = 14.05$

This table shows only the extent to which gains on the two tests tend to vary concomitantly. The correlation coefficient of gains on the training and functional tests is $+ .45 \pm .074$. The relationship is linear as determined by the Blakeman short test for linearity. Thus, it is evident that a gain on the training test is generally accompanied by a gain on the functional test, but the greatest gain on the former is not accompanied by the greatest gain on the latter, nor is the smallest gain on the training test accompanied by the smallest gain on the functional test.

Referring to Table XI, we note that a gain of forty to fifty points on the training test may be accompanied by a gain of from fifteen to thirty-nine points on the functional test, but is more likely to be accompanied by a gain of seventeen points.[2] A more extreme case is that of the column containing the training gains of from thirty to forty, in which the functional gains range from zero to forty-four. The most probable gain is four points. Thus, a gain of forty to fifty points on the training test is accompanied by a gain of seventeen points on the functional test, and a gain of thirty to forty points on the former is accompanied by a gain of four points on the latter.

So far, then, it has been found that there is a general tendency for the gains on the two tests to vary concomitantly to the extent of about $.45 \pm .074$. This represents the extent to which transfer does occur, but does not measure the proportion of the gain in knowledge which transfers to a practical situation.

Partial Correlation as a Measure of Transfer

By observing students at work in the classroom and laboratory, the writer formulated some hypotheses concerning the contributory factors in a student's ability to apply chemical information. She wished to know if those students who learn the greatest number of facts are better able to deal with practical situations than are those students who learn fewer

[2] Formula $x_{\text{training}} = r_{T.F.} \frac{\sigma \text{ training}}{\sigma \text{ functional}} y_{\text{Functional}}$.

facts during the same course. Often this assumption is made. From among those students who amass the same amount of information, do those of higher mental age show greater ability to deal with practical situations? The method of partial correlation offers a quantitative means of testing these hypotheses.

By the partial correlation technique, the training gains can be held constant and the relation of gains on the functional test to mental age can be computed. The coefficient of correlation of mental age and gain on the functional test with gain in training held constant ($r_{MF\text{-}gains.\ T\text{-}gains}$) is .052. The correlation of training and functional gains with mental age held constant ($r_{T\text{-}gains\ F\text{-}gains.M}$) is .44. The zero order tables from which the first order coefficients were obtained are given below.[3] The zero order coefficients are low but all are linear, as determined by the Blakeman short test for linearity.

TABLE XII

Correlation of Functional Gains and Mental Age
High School Experimental Group

Functional Gains	Mental Age															
	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	fy
0-4					1		1									2
5-9					1				2					1		4
10-14	1	1					1	1								4
15-19			1		1		1	1	2	1		1				8
20-24								1			1		1			3
25-29		1				1	1		1		1				1	6
30-34				1			2		2						1	6
35-39					1	1		1	2	1	1					7
40-44							2	1	1							4
45-49					2	1			1	2					1	7
50-54																0
55-59									1							1
fx	1	2	1	1	6	3	8	5	12	4	3	1	2	3		52

$r = .14 \pm .091$
$Mx = 197.10$
$My = 27.87$

[3] See Table XI for correlation of gains on functional and training tests.

TABLE XIII

CORRELATION OF TRAINING GAINS AND MENTAL AGE

High School Experimental Group

Training Gains	Mental Age 160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	fy
0- 9		I														I
10- 19									I							I
20- 29			I			I	I	I		I				I		6
30- 39						I	I	4	I	2						9
40- 49						I		I	I	4		I	I	I	I	11
50- 59	I			I	2				I		I					6
60- 69		I							I	4	I				I	8
70- 79							I	I							I	3
80- 89												I				1
90- 99								I			I					2
100-109					I					I		I				3
110-119											I					1
fx	1	2	1	1	6	3	8	5	12	4	3	1	2	3		52

$r = .218 \pm .090$

$My = 52.58$

$Mx = 197.10$

It is evident from the above figures that when training or knowledge gains are held constant, there is zero correlation between functional gains and mental age. Within the limits of the ages here represented, ability to apply chemical information is not a function of mental age. The relationship between gains on the training and functional tests, with mental age held constant, is somewhat higher, but does not indicate any great amount of transfer. It is to be expected that the gain in ability to apply knowledge of chemistry would bear some positive relationship to gain in knowledge of chemistry, but the correlation obtained here also is not high. Perhaps a functional test covering a greater variety of situations and hence providing for the functioning of a greater number and wider variety of facts might show more positive results. The functional test used was perhaps too brief and too narrow in scope to furnish an opportunity for a wide variety of factual material to function.

The raw gains used above are not comparable since the

actual zero points on the two tests are not known, and since the units on the two scales are not comparable. It is perhaps true that the zero point on the training test is about eleven and on the functional test about thirty-six. Thus, a score beween thirty-three and thirty-six on the functional test is not three times as great as a score between eleven and twelve on the training test. The functional test was so constructed that those items which the majority of students answered correctly on the trial test came first, while the more difficult ones, as determined by the number of students who failed to answer them correctly on the trial test, were placed toward the end. Hence, within the test itself, point gains are not comparable, since the items were arranged approximately in ascending order of difficulty. Therefore a further problem arose; namely, to convert the scores on the two tests into comparable terms. This furnished a third measure of transfer, based upon standard scores.

So far, we have found that, whether intelligence is considered or not, there is a correlation of about + .45 between training and functional gains and that for given gains on the training test, there is zero correlation between mental age and functional gains. We have not yet obtained a quantitative statement of the proportion of the gain on the training test which transfers to the functional test. This constitutes the task of the third and final measure of transfer used in this study.

Gains in Terms of Variability as a Measure of Transfer

In order to accomplish this, the gains on both tests were reduced to standard scores based on the test scores of eighty high school students who had just completed a course in chemistry. The data for these students are shown in Tables XIV and XV. It is well to recall here the caution that the validity of this technique depends upon whether or not this group of eighty is typical in general of high school students of chemistry. There is some indication that this group is not typical, as will be seen by a comparison of the mean and

standard deviation with the norms for a group of 663 students who took the training test.

TABLE XIV

SCORES OF GROUP OF EIGHTY ON FUNCTIONAL TEST

Score	Frequency
25- 29	2
30- 34	1
35- 39	5
40- 44	7
45- 49	5
50- 54	11
55- 59	10
60- 64	5
65- 69	6
70- 74	12
75- 79	5
80- 84	3
85- 89	4
90- 94	2
95- 99	0
100-104	1
105-109	1
Total	80
Mean	61.13 ± 1.85
S.D.	17.55 ± 1.31

TABLE XV

SCORES OF GROUP OF EIGHTY ON TRAINING TEST

Scores	Frequency
0- 9	1
10- 19	3
20- 29	3
30- 39	9
40- 49	12
50- 59	14
60- 69	17
70- 79	8
80- 89	3
90- 99	3
100-109	5
110-119	2
Total	80
Mean	58.88 ± 2.23
S.D.	23.80 ± 1.58

The mean and standard deviation for this same test based on the scores of 663 students, as given in the norms in the test manual, are 65 and 35. Since no similar data were available for the functional test, the standard deviation of a group of eighty, for whom both training and functional scores were available, was used to determine standard scores for the experimental group. It must be remembered that the group of eighty is not a typical sampling of the group of 663.

The mean and standard deviation for the group of eighty were respectively 61.13 and 17.55 for the functional test, and 58.88 and 23.80 for the training test. Expressed in terms of the standard deviation for the large group, the gains for the experimental group of fifty-two were 1.55 S.D.[4] on the functional test and 2.19 S.D. on the training test. Thus, a gain of 2.19 S.D. on the training test is accompanied by a gain of 1.55 S.D. on the functional test. This represents a genuine transfer of about seventy-one percent.

A Summary of the Three Techniques Used to Estimate the Amount of Transfer

Three means of measuring the transfer from knowledge of chemistry to the application of such knowledge have been used in this study. They are as follows:

1. The correlation coefficient measures the extent to which the gains on the training and functional tests tend to vary concomitantly. The results indicate that a student who makes a great gain on the training test will probably make a fair gain on the functional test. It does not give any indication of how much of what is learned actually transfers to a practical situation.

2. The coefficient of partial correlation was used here to measure the tendency of training and functional gains to vary concomitantly with mental age held constant, and the relation of functional gains to mental age with the training

[4] $\frac{27.27}{17.55}$ for functional test and $\frac{52.18}{23.80}$ for training test.

gains held constant. The former does not differ greatly from the coefficient of relationship between training and functional gains regardless of mental age. With training gains held constant there appears to be little if any relationship between mental age and functional gains.

3. In terms of standard scores, seventy-one percent is the amount of transfer from knowledge of, to ability to apply chemistry. This measure is perhaps the most reliable of the three since the gains are in comparable form. All three measures, however, indicate that there is some transfer.

II

Residual Transfer

A. Selection and Equating of Groups. To determine the permanence of the gains after some years had elapsed, ninety-six freshmen from Western Maryland College were tested in similar fashion. Some had taken a course in high school. None was taking or had taken a course in chemistry in college. These students were divided into two comparable groups on the basis of the Thurstone Psychological Examination. Since it was impossible to follow the two high school groups mentioned in section I after the completion of the course in high school, a college group was studied. It must be kept in mind that this is not the same group as the immediate-transfer group.

B. Final Tests and Results. A year later these same college students were tested again, using Form B of the training test and the single form of the functional test. The results are summarized in Table XVI. The term "chemistry group" designates those students who have studied chemistry in high school from one to three years previously and who are not enrolled in a course in chemistry in college. The term "non-chemistry group" refers to the group of students who have not studied chemistry in high school or in college.

TABLE XVI

Comparison of College Groups

	Chemistry Mean	Group S.D.	Non-Chemistry Mean	Group S.D.
Thurstone	162.50	52.84	162.50	63.25
Initial Iowa A	42.34	22.95	12.45	5.80
Initial Functional	38.72	10.55	36.09	6.70
Final Iowa B	44.28	21.25	20.25	13.70
Final Functional	41.48	14.20	40.64	16.20
Number	29		11	

Gain on Iowa Test 1.94
Gain on Functional Test 2.76

Examination of Table XVI shows the two groups to be equivalent in intelligence at the beginning of the freshman year in college. The assumption, on the basis of this equivalence, that they were also equivalent in intelligence while in high school will be discussed on pages 40 to 43.

Due to the fact that the non-chemistry group scored lower on both of the initial tests, greater gains over the same period might be expected from them than from the chemistry group. Due to the practice effect of the tests within the control group, greater gains might be expected of the non-chemistry group. Both of these factors operate to increase the relative gain of the control group, and may in part explain the somewhat greater gain shown above. Since the groups were small, the probable errors were not calculated and it is impossible to say whether the above gains are significant. For this reason, the actual point gains for the control group are omitted from Table XVI.

Assuming that the college group is not less intelligent than the high school groups used in the previous section of this study, a comparison of the college and high school groups may be made. After a period ranging from one to three or four years since taking chemistry, this group, now in college, has a residue on the training test of three and four-tenths times that of the non-chemistry group now in college. At

the end of the course in chemistry the high school group scored four and one-half times as high as the non-chemistry group. Table XVII shows these figures.

TABLE XVII

Comparison of High School and College Experimental Groups

	High School Group		College Group	
	Mean	S.D.	Mean	S.D.
Iowa Training B	63.04	24.64	A 42.34	22.95
Functional	63.31	13.29	38.72	10.55
Number	52		29	

Although there appears to be a residue of about seventy-two percent on the training test, further analysis of the data reveals two probable sources of error: (1) the lack of comparability of the high school and college groups, and (2) the somewhat greater difficulty of Form B of the training test.

In regard to the first, it must be remembered that the means compared above are not the means of the same group tested on two different forms of the training test at two different times. These figures represent two different groups of students and are comparable only in so far as the scores of any high school and college groups in general are comparable. Assuming that only the better high school students enter college, the mean of 42.34 represents the mean score of the better high school students—those who went to college. Hence the true residue is probably less than Table XVII indicates, and the difference in the means of the high school and college groups is less. This selective factor affects the functional residue similarly.

In regard to the lack of comparability of the two forms of the training tests, an examination of the following data given in the test manual accompanying the Iowa Training Tests shows that Form B is perhaps the harder form. The difference, however, is slight.

	No. of cases	Mean	S. D.
Iowa, Form A	1726	70	34
Iowa, Form B	663	65	35

We must examine carefully the comparison made in Table XVII of the mean score for the high school group on the more difficult Form B of the training test with the mean score for the college group on the easier Form A. Since the mean for Form A, as given in the test manual, is slightly higher than the mean for Form B, the latter is probably a more difficult test. Table XVII compares the mean score on the more difficult Form B for the high school group with the mean score on the less difficult Form A for the college group. If the difference in difficulty of the two tests is significant, this also would make the residue appear to be greater than it really is. Had both groups taken the more difficult Form B, the mean for the college group probably would have been a little lower and the difference between the two groups would have been less. It is impossible to say how much less the residue may be. There is no reason to assume that it may be more. Since only one form of the functional test was prepared, this factor of non-equivalence of the test forms would not affect the means for the two groups on the functional test.

Thus, the selective factor of college entrance tends to make the residue appear greater for both the training and functional tests. The greater difficulty of the training test given to the high school group operates in the same direction for the training gains. At this point, it is safe to assume that the mean scores on both the functional and the training tests for the college group are lower than is shown by Table XVII. Stated in another way, it is safe to assume that from the completion of a course in chemistry in high school to the freshman year in college the loss in functional and factual knowledge of chemistry is even greater than is shown by Table XVII. The mean for the college group on the training test is less than the mean shown by a group of high school students at the end of the course in high school, but

not so low as the mean at the beginning of the course (Table XVI). In so far as the high school and college groups are comparable, this indicates that some residue of chemical information remains after the study of chemistry in high school. The gains on the training test appear to be more permanent than the functional gains. Since the mean for the college group on the training test, Form A, is compared with the mean for the high school group on both Form A as pretest and Form B as final test, the lack of equivalence of the two test forms would not affect the results. The selective factor of the college group would operate here, but would not account for the great difference noted.

On the functional test, the gains seem less permanent, if indeed they show any permanence at all. Comparison of the initial and final scores for the college group with the initial and final scores for the high school group reveals no residue of functional knowledge after three or four years have elapsed after taking chemistry. (Compare Table XVI with Tables IV, V, VIII, and IX.)

Making the same comparison for the non-chemistry groups, great similarity will be noted. Table XVIII gives the comparative figures for the high school and college non-chemistry groups.

TABLE XVIII

Comparison of High School and College Control Groups

	High School Group		College Group	
	Mean	S.D.	Mean	S.D.
Iowa Training	B 13.59	10.29	A 12.45	5.80
Functional	41.58	10.01	36.09	6.70
Number	41		11	

Here also the two factors mentioned above operate, and the residue may appear somewhat larger than it really is. It is quite probable that the loss is greater than the figures indicate due to the lack of equivalence of the two forms of the

training test and due to the fact that the better high school students enter college. The small size of the college group makes questionable the significance of these data.

Assumed Equivalence of the College Groups

When equating the college groups, as shown in Table XVI, the assumption was made that since the two groups were equivalent in intelligence in 1932, they were also equivalent one, two, or three years earlier. To discover if there were any forces operative which might make this assumption invalid, two factors were investigated: (1) the influence of choice of chemistry upon subsequent achievement, and (2) the relationship of choice or avoidance of chemistry to intelligence.

In regard to the first factor, the question is, may not those students who elect to take chemistry do so because they have a special interest in or a special aptitude for chemistry? If this be the case, would this special interest account for not only greater success in the study of chemistry, but also for greater retention of the knowledge gained? To discover the effect of choice upon achievement in chemistry, questionnaires were prepared to segregate the students who took chemistry from choice from those who took it because it was a requirement. These questionnaires were given to a group of college students who had studied chemistry in high school. In an effort to find which students could take chemistry in high school but chose not to, and which ones did not have an opportunity to take it, the questionnaire was given also to a group who had not studied chemistry in high school. These groups also took the training and functional tests. The results are given in Tables XIX and XX.

TABLE XIX

College Scores on Training and Functional Tests

Chemistry Groups

	Chemistry-Choice Group	Chemistry-No-Choice Group
Functional	38.64	46.78
Training	49.35	42.28
Number	67	18

Difference in favor of no-choice group:

Functional	8.14
Training	-7.07

TABLE XX

College Scores on Training and Functional Tests

Non-Chemistry Groups

	No-Chemistry-Choice Group	No-Chemistry-No-Choice Group
Functional	32.48	34.33
Training	16.33	18.83

Difference in favor of no-choice group:

Functional	1.85
Training	2.50

Since these groups are so small, no valid final conclusions can be cited; but from the above data, there seems to be a rather strong indication that students who elect to study chemistry achieve no greater success in chemistry than do those students who take it as a requirement. The factor of choice seems not to be influential.

The second factor raised this question: may not those students who elect to study chemistry be more intelligent than those who elect not to study it? To find if there were a tendency for the more intelligent students to select chemistry and for the less intelligent ones to avoid it, a study of the four groups mentioned above was made. The status of the chemistry-choice and chemistry-no-choice groups are given in Table XXI.

TABLE XXI

THURSTONE, TRAINING AND FUNCTIONAL SCORES FOR CHEMISTRY GROUP

	Chemistry-Choice Group		Chemistry-No-Choice Group	
	Mean	S.D.	Mean	S.D.
Thurstone	178.60	58.25	145.33	49.49
Functional	39.44	12.15	45.56	2.72
Training	46.83	25.94	43.33	3.88
Number	45		9	

Difference in favor of the chemistry-choice group:

Thurstone	33.27
Functional	- 6.12
Training	3.50

Again the small size of the chemistry no-choice group makes final conclusions doubtful. These data do seem, however, to indicate that there may be some tendency for the less intelligent students not to elect to take chemistry. The difference in Thurstone scores may be partially accounted for by the inexperience of the no-choice group with tests of this sort, since the majority of these students came from small schools where intelligence testing may not be a part of the regular program. The students in the chemistry-choice group came mainly from large high schools where intelligence tests are more frequently a part of the regular record system. This, however, is an assumption which must be tested by further investigation in the future.

The difference on the functional test is in favor of the no-choice group. This may be accounted for, perhaps, by the small number in this group, or by the fact that laboratory facilities are frequently inadequate in small high schools and, therefore, the students themselves must often substitute or improvise laboratory materials. It does not appear reasonable to believe that the element of choice may condition achievement on either the training or the functional test.

These studies of the influence of intelligence upon subse-

quent achievement in chemistry do not invalidate the data presented in Tables XVI, XVII, and XVIII or the conclusions based on them. Awaiting further controlled experimentation in regard to these problems, the data of these three tables may be taken as a fair indication that there is some residual knowledge of chemistry. We may conclude that a significant residue of knowledge is retained three years after taking a course in chemistry, but that there is little if any residue of functional knowledge. These conclusions are reached without reference to the elements of choice or of intelligence.

It may be possible that there are additional factors, other than those investigated here, which condition achievement on the tests used in this study. To the writer, however, no other factors seemed to affect one group more than the other. Therefore, on these bases, the writer believes that the salient factors which might affect either group unduly have been cared for.

CHAPTER IV

Summary and Conclusions

I

Conclusions Regarding Immediate Transfer of Training From Knowledge of Chemistry to Ability to Apply it

Summary of Procedure

The major task of this study is to discover the amount of transfer which takes place from the acquisition of knowledge of chemistry to the ability to apply this knowledge. The technique used was to test a group of high school students before and after they had taken a course in chemistry, and to compare their gains with the gains made by an equivalent control group not studying chemistry. To secure a quantitative measure of transfer, four methods were used: (1) comparison of the raw score gains of the experimental and control groups on the training and functional tests—an adequate measure of the amount of transfer only when the point gains are comparable, (2) correlation of gains on the training and functional tests, which measures the extent to which the scores on the two tests tend to improve together but does not measure the amount of transfer, (3) partial correlation of (a) training and functional gains with intelligence held constant and (b) functional gains and intelligence with training gains held constant, and (4) comparison of sigma gains on the two tests, which measures the percent of transfer which really takes place because the units are in comparable terms. Detailed exposition of each of the methods is found on pages 24 to 35.

Table X, page 23, shows the chemistry and non-chemistry groups at the beginning of the experiment to be practically equivalent in the three factors upon which they were equated: mental age, initial score on the training test, and initial score

on the functional test. The table also gives the differences in intelligence quotient and chronological age, showing the experimental group to be slightly brighter (I.Q of 108.6 ± .99 as against 104.1 ± 1.04), and nearly ten months younger chronologically than the control group. Both of these differences operate to increase the possible gains made by the experimental group. The correlation of each of these factors with the gains on both the training and the functional test corroborates this statement. The correlation coefficients are given on pages 61 to 64. Since the difference in intelligence quotient is not great and since the correlation between the test gains and intelligence quotient are low, the difference has been disregarded. Consequently, chronological age is left as the only significant difference which is to be noted at the beginning of the experiment. It is highly improbable that a difference of ten months in chronological age alone could account for the great gains made by the experimental group. The correlation coefficients of chronological age with test gains are negative but low, and since the more important factors of mental age, intelligence quotient, and initial scores on both tests are equivalent, the greater part of the difference can be attributed only to the class and laboratory instruction in chemistry.

Conclusions

As to the major investigation of immediate transfer, two valid conclusions can be drawn:

1. A group of students who study chemistry in high school for one year make significant, measurable gains in knowledge of chemistry.

2. A gain in knowledge of chemistry is accompanied by a significant but smaller gain in ability to use this knowledge in meeting situations requiring a knowledge of chemistry and in interpreting popular scientific literature.

From the data examined, there is some slight evidence that students of less intelligence tend to avoid taking courses in chemistry. This inference should be subjected to further

investigation under better controlled conditions to take care of such variables as differences in size of schools, pupil experience with intelligence tests, and the like.

Although the writer makes no attempt to evaluate any aims set up by curriculum makers for the teaching of chemistry in high school, the following aims appear attainable for the pupils who took part in this experiment:

1. To increase their ability to solve everyday problems of home and shop in which chemistry is involved, and

2. To increase their ability to interpret popular scientific literature.

The investigation yields no evidence that students who elect to take a course in chemistry achieve any greater success in it than students who are required to take it. There is no evidence that the former are able to make any greater use of what they learn about chemistry. This is an interesting observation but not so significant as the fact that students who had no opportunity to take chemistry tend to avoid taking it when the opportunity arises.

II

Conclusions Regarding Residual Transfer After a Lapse of One to Four Years Since Taking a Course in Chemistry

The second problem was to discover if there is any permanence of transfer from knowledge of chemistry to ability to apply it. A similar technique to that used with high school groups was applied to two groups of college students. A comparison of the two groups with the high school groups reveals the relative permanence of the gains in the two traits.

The data used in Part Two, limited as they are by the lack of comparability of the high school and college groups,[1] indicate that there is some permanence of the knowledge which is acquired in a course in chemistry in high school. The fol-

[1] See discussion on pages 37 to 40.

lowing conclusions are warranted by the data of this portion of the study:

1. A lapse of from one to four years after taking a course in chemistry in high school leaves a significant, measurable residue of knowledge of chemistry. During one year at college there is no apparent further loss of this knowledge even though the students no longer study chemistry. Obviously, the actual loss of knowledge of chemistry which occurs, takes place soon after the completion of the course. From then on the loss is too slow to be detected in a single school year.

2. Since there is no apparent difference between the initial scores of the high school and college experimental groups on the functional test, it appears that functional gains are quickly lost. Within the limits of this study, students show no significant residue of functional knowledge after a lapse of from one to four years following a course in chemistry. During the college year, there is no significant gain or further loss in either functional or factual knowledge for either the experimental or the control group. Obviously whatever loss occurs takes place soon after the completion of a course in chemistry and, therefore, was in existence before the beginning of this experiment. Examining the data for the control group, we note that there is no significant gain during the period of the experiment beyond what would be expected from the practice effect of the tests. Since there is no significant difference between the scores of the high school and college non-chemistry groups, it would appear that the acquisition of functional and factual knowledge of chemistry is not a matter of maturation alone. The major differences between the experimental and control groups must be attributed to the course in high school chemistry. This agrees with Webb's findings regarding laboratory resourcefulness. From these data, it appears that instruction and directed experience are more influential factors in developing skill in solving practical problems of chemical nature.

III

Summary of General Conclusions

The following conclusions, summarized from the foregoing pages, are offered here without comment.

1. The study of chemistry for one year in high school yields significant, measurable, and relatively permanent gains in the knowledge of chemistry.

2. Growth in knowledge of chemistry is accompanied by significant but smaller gains in the ability to apply this knowledge.

3. Retention of the facts of chemistry is sustained over a longer period than is the ability to apply the facts.

4. Both the acquisition of knowledge of chemistry and the ability to apply such knowledge are largely the resultants of instruction in chemistry.

IV

Problems for Further Study

There is something ironical about the fact that the solution of one problem usually raises several new and more difficult ones. The following list of pertinent problems proves that the present study is no exception in this respect. Some of the following problems were considered by the writer, but since no separate data were secured for any of them, no formal report is included in this paper.

1. Since the data of this study indicate that there is a substantial amount of transfer from theory to application in the field of chemistry, it would be valuable, as suggested in Chapter I, to discover how to increase the amount. This offers a fruitful field for investigation and the results would be of value to teachers of chemistry.

2. The results of this study reveal a greater permanence of factual than of functional knowledge of chemistry. Although frequently the teacher puts greater emphasis on the

factual phase of chemistry, it is generally believed that knowledge gained through experience is more meaningful and hence is more useful and more permanent. This is not in accordance with the findings of the present study and indicates a need for further experimentation. If this experiment might be extended over a longer period of time so as to follow a large group of high school students for at least three years after they complete a course in chemistry, it would be possible to secure reliable data on the permanence of both factual and functional gains. Since it is generally conceded that functional knowledge is one of the most valuable products of the study of chemistry, some means should be secured for making it more permanent.

3. The question of the relation of the two factors of intelligence and of choice to subsequent achievement in chemistry, both from the factual and the functional point of view, offers another promising field for investigation. An experiment should be carried on with high school students at the time they elect to study chemistry. In this way, the assumption involved in the equating of the college groups may be avoided.

4. The problem of choice of chemistry suggests a further study of the tendency for children consistently to avoid or to elect chemistry. The limited data here indicate that students who had no opportunity to elect chemistry in high school do not elect to take it when given an opportunity to do so in college. Similarly, a larger percent of those who elect to take a course in chemistry in high school also elect to take it in college. These findings need further verification.

5. A study needs to be made of the influence of other science courses previously studied upon achievement in chemistry. From the data of this study, it appears that in two respects at least—the acquisition of factual and of functional material in chemistry—a course in chemistry based upon a year-course in general science is most beneficial. A group which had studied chemistry and general science scored higher on both the training and the functional tests than did

a group which had studied only chemistry or biology or both chemistry and biology. These groups were small and their intelligence was not taken into consideration. It is suggested, therefore, that this problem be investigated under better controlled conditions before any conclusions can be formulated.

6. A study also needs to be made of the effect of size of school and quality and quantity of laboratory facilities upon ability of the students to apply knowledge of chemistry. The writer suggests in Chapter III that, due to the need for ingenuity in performing required experiments with limited supplies, it might be assumed that in practical ability students in small schools excel their more fortunate neighbors in larger schools. The assumption was made to explain the higher scores of the members of the chemistry-no-choice group on the functional test, but its verification suggests an interesting challenge.

7. A study of sex differences in regard to the acquisition of both factual and functional knowledge might be launched as a supplement to Webb's study. By using a training and functional test for both initial and final testing, the chief weakness of Webb's study, the failure to measure the groups in both traits before the training period as well as afterwards, may be corrected.

The problems suggested for further investigation indicate the richness of the field for students who are interested in chemical education. The writer believes that all of them are feasible and involve important questions. The list is by no means exhaustive.

APPENDIX A

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chological Review, Monograph Supplement, 1908, 38, 56-102. Transfer from one type of memory training (order of sound intensities) to other types (poetry, tones of gray, geometrical figures, etc.).

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Sleight, W. G., Memory and Formal Training. British Journal of Psychology, 1911, 4, 386-457. Experiment in the field of memory.

Thorndike, E. L. and Woodworth, R. S., The Influence of Improvement in One Mental Function Upon the Efficiency of the Other Functions. Psychological Review, 1901, 8, 247-261, 384-395, 553-564. Experiments in transfer in the field of sensory discrimination.

Winch, W. H., The Transfer of Improvement in Memory in School Children. British Journal of Psychology, 1906-1908, 2, 284-293; 1909-1910, 3, 386-405. Experiment in transfer from one type of memory material (poetry) to memorization of material in the school subjects (history and geography).

———, The Transfer of Improvement in Reasoning in School Children. British Journal of Psychology, 1922-23, 13, 370-381. Experiment in transfer from specific type of reasoning (arithmetic) to general reasoning.

———, Accuracy in School Children. Does Improvement in Numerical Accuracy Transfer? Journal of Educational Psychology, 1910, 1, 557-589; 1911, 2, 262-271. Experiment in transfer from computation to reasoning in arithmetic.

III. Experimental Studies of transfer from theory to practice:

Dorsey, M. F. and Hopkins, L. T., The Influence of Attitude Upon Transfer, Journal of Educational Psychology, 1930, 21, 410-417. An experiment in transfer of knowledge of a method of study, transfer of knowledge of Latin, and transfer of a method of reasoning.

Frutchey, F. P., Measuring the Ability to Apply Chemical Principles, Educational Research Bulletin, 1933, 12, No. 10, 255-260. Ex-

periment in transfer from knowledge to ability to apply knowledge in the field of chemistry. The study is chiefly concerned with a comparison of the essay and objective type of examination.

Lehman, H. C., A Class Experiment in Transfer of Training. Journal of Applied Psychology, 1933, 17, No. 1, 77-82. Experiment in transfer from generalized mathematics (algebra) to specific (arithmetic).

Meredith, G. P., Consciousness of Method as a Means of Transfer of Training. Forum Education, 1927-28, 5, 37-45. Experiment in transfer from study of science to ability to define words, with and without the study of the essentials of a good definition.

Olander, H. T., Transfer of Learning in Simple Addition and Subtraction, Elementary School Journal, 1930-31, 31, 358-369; 427-437. Experiment in transfer from study of addition and subtraction facts to other addition and subtraction facts, with and without generalization.

Overman, J. R., An Experimental Study of the Effect of the Method of Instruction on Transfer of Training in Arithmetic, Elementary School Journal, 1930-31, 183-190. Experiment in transfer in addition and subtraction with varying degrees of generalization.

Scholchow and Judd, C. H. (Reported in Judd, C. H., The Relation of Special Training to General Intelligence. Education Review, 1908, 36, 28-42). An experimental study of transfer from knowledge of to ability to apply the principle of refraction in hitting a target under water.

Webb, H. A., Testing Laboratory Resourcefulness, School Science and Mathematics, 1922, 22, No. 3, 259-267. Experiment in transfer from knowledge of chemistry to ability to solve problems in the laboratory.

Woodrow, H., The Effect of Type of Training Upon Transference, Journal of Educational Psychology, 1927, 18, No. 3, 159-172. An experimental study of memory with instruction in a method of memorizing.

APPENDIX B

I. Objectives of chemistry found in courses of study.

A. Analysis of objectives listed in nineteen courses of study in chemistry, Bulletin No. 17, 1932, Monograph No. 22, Instruction in Science, U. S. Department of Interior, Office of Education.

	Times mentioned.
1. Knowledge Objectives:	
*a. To acquire knowledge which will produce a better understanding of our environment	7
b. To acquire the knowledge necessary for future courses in science or to prepare for college	7
c. To acquire knowledge of the fundamental principles of the subject	6
*d. To acquire a body of facts which will enable one to read scientific literature	5
*e. To acquire a knowledge of the application of principles to industry	5
f. To acquire knowledge to increase the general culture of the individual	3
g. To acquire the knowledge necessary to correct superstition and erroneous beliefs	1
h. To acquire knowledge which will function to secure the objectives stated in the bulletin on Cardinal Principles of Secondary Education.	
(1) Health	5
(2) Command of the fundamental processes	0
*(3) Citizenship	3
*(4) Worthy home membership	5
(5) Vocation	3
(6) Worthy Use of Leisure	0
(7) Development of ethical character	1
2. Abilities:	
a. To develop the ability to think scientifically	9
b. To develop the power of observation	3
c. To develop the ability to express ideas in clear and coherent English	1
d. To develop the ability to use the scientific instruments in the laboratory	2
3. Attitudes:	
a. To develop attitudes of appreciation of	
(1) Contributions of scientific method	1
(2) Contribution of science to mankind	7
(3) The great men of science	1
(4) Nature	1
4. Ideals and habits:	
a. To acquire ideals or habits of accuracy, persistence, honesty, self-control, truth, etc.	4
b. To inculcate a safe, sane, reverent attitude toward science	1

* Items related to the two objectives selected for this study.

c. To evolve high standards of conduct in personal and group life..... 1

5. Interests:
*a. To acquire an appetite for scientific reading..... 2
b. To acquire an interest in nature..... 1
c. To acquire wholesome interests which may be used to enjoy spare time..... 2

B. Baltimore City Course of Study, Science Course of Study for Junior and Senior High Schools, City of Baltimore, Department of Education, 1927, Meyer and Thalheimer, Baltimore, Maryland.

1. Objectives of Chemistry I:

a. To help develop the pupils into well informed, cultured citizens.
*b. To get the pupils to read intelligently newspaper and magazine articles on commercial adaptation of chemical principles and discoveries.
c. To prepare pupils for professions in which chemistry bears a part.
d. To train the pupil in scientific thinking.

II. Objectives and values given in science methods textbooks and magazine articles:

A. Summary of aims and objectives from authoritative sources, general and specific. J. O. Frank, Teaching of First Year Chemistry, Fourth Edition, 1927, Oshkosh, Wisconsin. Pages 26-29. Also The Teaching of High School Chemistry by the same author, 1932, J. O. Frank and Sons, Publishers, Oshkosh, Wisconsin.

1. Instruction. Instruction is an important part but not the whole of teaching. Of greater importance is understanding.
2. Training, skills, abilities, habits peculiar to the subject and operations and manipulations which belong to it. Study, economy of time and materials, accuracy, neatness, etc., as well as specific skills.
3. Inspiration. Ideals and appreciations of chemistry and chemists.
4. Discipline. Judgment, scientific thinking applied to all fields.
*5. Power to interpret. Freedom from superstition, fear, and prejudice through schooling in scientific method. Pick false from the true. Democracy rests upon this freedom, preventing them from becoming prey to quacks. Perspective.
6. Exploration and guidance. "Newly discovered gate into a beautiful and unexplored garden." Show the pupil the direction of his abilities and interests. Find and develop abilities.
7. Recreation. Create in pupil the ability to see beauty in everything around him.

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* *Ibid.*

B. Report of Committee on Chemical Education of American Chemical Society. Frank, J. O., Teaching First Year Chemistry, 1927, page 29. Also found in Journal of Chemical Education, May 1924, Vol. I, pages 87-93. Neil E. Gordon.

*1. To show the service of chemistry to the home, to health, to medicine, to agriculture, to industry, etc.—in a word, to show the service of chemistry to the nation.
2. To develop this service in chemistry around minimum standard topics, and in doing so, to see that these minimum requirements are so thoroughly taught that they may be built upon as a foundation in college.
3. To develop his own order of developing the listed topics.
4. To train the student in keen observation and exact reasoning.
5. To develop a careful correlation between recitation and experiment with a minimum amount of repetition.
6. To encourage the student to keep notebooks which shall be an accurate record of laboratory experiences expressed in concise, clear English.
7. To encourage chemistry being placed in the fourth year of high school, after students have had a year of general science and a year of biological science or physics, or preferably both.
8. To build upon the earlier science courses and knit them together in the best possible manner.
9. To encourage students to use reference books in addition to the textbook.
10. To help pupils to find themselves—i. e., to discover whether they have aptitude for further study of chemistry or applied science, and, if so, to encourage such students to continue their study of science in university or technical school.
11. The teacher is urged throughout the course to stress general principles involved in the specific cases studied.

C. More specific aims. Pages 29-30, Frank, J. O. *Ibid.*, 1927. (Also quoted in Powers, 1925.)

*1. To give to pupils a broad and genuine appreciation of what the development of chemistry means in modern social, industrial, and national life.
2. To satisfy the natural interests in the things and forces of nature with which men are surrounded and with which they must deal; to give information which is interesting purely for its own sake.
3. To provide opportunity for the student to become acquainted with applications of chemistry to industry for the purpose of educational and vocational guidance and possibly to furnish a beginning of vocational training.
4. To develop such broad concepts and natural laws as the ultimate composition and indestructibility of matter, nature of chemical composition, interrelation of chemical elements, etc., to the end that science and reality may function in place of superstition and uncertainty in explaining natural phenomena.

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* *Ibid.*

5. To contribute such specific ideals, habits, and concepts as those of accuracy, achievement, persistency, open-mindedness, honesty, cause and effect, which are essential to the study of science.
6. To develop system, order, neatness, and possibly other attributes to the end that they will function in the ordinary affairs of life.
7. To afford in some measure an opportunity to show the importance of scientific research and to stimulate the spirit of investigation and invention on the part of the student.
8. To give pupils an opportunity to indulge in the playful manipulation of chemical material in order that they may explore the world of reality as widely and as deeply as possible.
*9. To provide opportunity for acquaintance with such applications of chemistry to public utilities in order that the student may more adequately fulfill the duties of citizenship.
*10. To provide an opportunity for acquaintance with such applications of chemistry as contribute to the maintenance of the health of the individual and the community.
*11. To provide opportunity for acquaintance with the elementary laws of nature which aid in understanding those citizenship problems which arise in connection with such topics as utilization of waste products, elimination of smoke, pure foods, etc.
*12. To make pupils able to read more intelligently and with greater interest, articles on chemistry in magazines and scientific books of a popular character.
13. To give such training as will result in increasing respect for the work of recognized experts.

D. Summary of aims of chemistry from the N. E. A. commission on the cardinal aims of secondary education. McAlpine, R. K., Some Aims in Teaching Elementary Chemistry, School Science and Mathematics, Vol. 28, page 154, Feb., 1928.

1. To give an understanding of the significance and importance of chemistry in our national life.
2. To develop those specific interests, habits, and abilities to which all science study contributes.
3. To build upon the earlier science courses and knit together previous sciences by supplying knowledge fundamental to all science.
*4. To give information of definite service to home and daily life.
5. To help pupils to discover whether they have aptitudes for further work in pure or applied science.

The author found that greater stress was given to numbers 1 and 4 above in actual classroom instruction and in science methods textbooks. It may look as if the course as taught "leads away from chemistry to medicine, to agriculture, to industry, and a hodge-podge of miscellaneous information about other fields." It is not the contribution

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* *Ibid.*

of chemistry to these fields that is in need of emphasis so much as the fact that these fields are able to furnish chemistry with problems to study.

E. Objectives of Chemistry. Stevens, Clarence P. New Courses in High School Chemistry. School Science and Mathematics, Vol. 32, 1932, pages 244-249. (Pandemic point of view.)

1. To train the pupil to recognize and appreciate the merit of scientific methods of thinking and in so far as possible, to apply this method, not only to scientific matter, but to all problems.
2. To establish an appreciation of modern chemical achievements and show how chemistry, often working through other sciences, has created our civilization.
3. To satisfy the normal interest in the materials and forces of nature; to show the scientific explanation of natural phenomena in order that truth may prevail instead of superstition.
4. To show the importance of scientific research and stimulate the spirit of investigation and invention; to encourage independent thinking through such devices as the project method.
5. To secure the interest and motivation essential to adequate learning through the study of things as well as words and through the satisfaction of creative work; to foster interest in chemistry.
6. To provide a fund of useful information in vocations or prevocational training.
7. To promote the use and development of chemistry for the betterment of humanity by enlisting the pupils and public in the problems of chemistry.
*8. To teach "consumer values" such as the intelligent use of common chemicals for medicine, insecticides, poisons, and for many other purposes.
9. To secure optimum results through the use of subject matter within the comprehension of all normal pupils and which gives a reasonable return in educational achievement for the time expended.
10. To give such training as will result in respect by the public for the work of recognized scientific experts.

F. Educational Aims in Teaching Elementary Chemistry. Coulson, F. C. Journal of Chemical Education, June 1929, pp. 1120-1125. The chief aims of the teaching of chemistry *should* be:

1. To give pupils an idea of the importance and significance of chemistry in our national life.
*2. To give information and definite service to home and daily life.
3. To develop specific interests, habits, and abilities which should be contributed to by all sciences.
4. To secure an element of continuity in science work.
5. To help the student discover whether he has an aptitude in applied science and to induce him to continue science studies in higher institutions.

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* *Ibid.*

In the above quotations frequent reference is made to two aims selected for this study. Although the wording differs in the various statements, the underlying thought is the same. The starred statements seem to the writer to be references to one or both of the following aims: (1) to give sufficient information of a functional nature to enable students to meet many practical everyday situations involving a knowledge of science, and (2) to enable students to read more intelligently popular scientific literature such as is found in magazines, newspapers, and books dealing with science from a popular point of view. The above lists of aims and values of chemistry are somewhat confused by the inclusion of aims for the teacher with values to the student. No attempt was made to separate them. They are given in complete form, showing the two aims selected as representing but a small part of what educators in general believe to be satisfactory aims for the teaching of chemistry.

APPENDIX C

Supplementary Tables

TABLE XXII

Status of High School Groups as to Previous Science Courses

	Chemistry Group No.	Percent	Non-Chemistry Group No.	Percent
General Science	19	36.54	12	29.27
Biology	2	3.85	11	26.83
Physics	2	3.85	0	0.00
G.S. and Biology	5	9.62	0	0.00
G.S. and Physics	4	7.69	1	2.44
Biol. and Physics	0	0.00	0	0.00
No Science	20	38.45	17	41.46
G.S., Biol., Physics	0	0.00	0	0.00
Total	52	100.00	41	100.00

TABLE XXIII

Correlation of Functional Gains and Chronological Age

Functional Gains \ C.A.	150	160	170	180	190	200	210	220	230	240	250	fy
0- 4			1	1	1							3
5- 9			1	1	1	1						4
10-14				2	1	3		2				8
15-19				2	4	3		1			1	11
20-24				1	1	1	1	1				5
25-29			1	1	3	3	1					9
30-34			1	2	1	6	1					11
35-39		1	1	2	3	1	1	1				10
40-44			1	2	1	2						6
45-49			3	2		3	1					9
50-54				1		1						2
55-59			1									1
60-64												0
65-69						1						1
fx		1	10	17	16	25	5	5	0	0	1	80

$r = -.138 \pm .074$

TABLE XXIV

Correlation of Training Gains and Chronological Age

Training Gains	C.A. 150	160	170	180	190	200	210	220	230	240	250	fy
0- 9							1					1
10- 19			1	2	2	2		1			1	9
20- 29			2	1	3	7	1					14
30- 39			1	3	5	5	2	1				17
40- 49				3	1	2	1	2				9
50- 59		3	6	1	3							13
60- 69				1	2	1						4
70- 79			1	1								2
80- 89				2								2
90- 99												
100-109	1	2										3
110-119		1										1
fx	1	10	17	16	25	5	5	0	0	1		80

$r = -.366 \pm .065$

TABLE XXV

Correlation of Iowa Gains and Intelligence Quotient

I.Q. \ Iowa Gains	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109	110-119	fy
70- 74		1											1
75- 79													0
80- 84			1			1	1						3
85- 89	1		2				1						4
90- 94				1	1	2							4
95- 99		2	1	3	1	2		2					11
100-104			1	2	1					1			5
105-109				4	4		1						9
110-114		3	3	2	5	1			1	1	1		17
115-119			1		5	1	5		1				13
120-124						1	2	1			1		5
125-129		1		1			1	1				1	5
130-134							1						1
135-139											1		1
140-144							1						1
fx	1	7	9	13	17	8	13	4	2	2	3	1	80

$r = + .382 \pm .064$

TABLE XXVI

Correlation of Functional Gains and Intelligence Quotient

I.Q.	Gains on functional												
	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	fy
70- 74							1						1
75- 79													0
80- 84			2					1					3
85- 89			1	1		2							4
90- 94					2		2						4
95- 99	1		3	1		1	1	1		2	1		11
100-104				1					2	1			4
105-109		2		2		1	1	2	2				10
110-114	1		1	3	2	2	1	4	1	1		1	17
115-119	1	2		1	1	1	2	2	1	2			13
120-124			1			1	1			1		1	5
125-129				2		1	1			1			5
130-134											1		1
135-139								1					1
140-144										1			1
fx	3	4	8	11	5	9	10	11	6	9	2	2	80

$r = +.202 \pm .072$

APPENDIX D

Tests and Questionnaires

Name..... High School.....

Year in High School .....

In connection with the tests you are taking, the following information is desired. Will you cooperate by answering these questions:

1. How many months have you studied chemistry?.....
2. Are you a member of a science club?.....
3. Have you ever entered a science essay contest?.....
   Were you awarded a prize?.....
4. Have you a Boy Scout or Girl Scout merit badge for science?....
   A Campfire Girl merit bead for science?.....
5. Do you read scientific magazines or books for any course other than science?..... If so, for what course?.....
6. How many scientific lectures, moving pictures or illustrated talks (aside from your science class) have you attended in the past year? .....
7. What commercial, industrial or municipal plants and factories have you visited and inspected in the last two years?.....
8. Have you a chemistry set or equipment at home?.....
9. What is your father's occupation?.....
10. In column 1 below list any magazines or newspapers which contain scientific material which you read. In column 2 check those which you read most frequently for scientific information. In column 3 check those which you like best as sources of scientific knowledge.

	1	2	3	
Sample	(1. The Scientists	1.	1.)	Sample. Do not check in here. If you read these magazines for scientific material write them in column 1 below.
	(2. Popular Science	2. V	2.)	
	(3. Cosmopolitan	3.	3.)	
	(4. Boys World	4. V	4. V)	
	(5. Nature Magazine	5. V	5. V)	
	1.	1.	1.	
	2.	2.	2.	
	3.	3.	3.	
	4.	4.	4.	
	5	5	5	

FUNCTIONAL CHEMISTRY TEST

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The Johns Hopkins University

Name ..... Age..... Date ..... Sex .....

Name of High School or College ..... City.....

General Directions: Do not write until told to do so. Do not turn a page unless so directed at the bottom of that page. Judge each item in the test carefully. Mark your answers as directed in each part. If you do not know, guess.

Score
Part I .....
Part II .....
Total .....

PART ONE

Directions: Below are described some situations which may occur in every-day life. Many of them do. Read the statement of each situation carefully. Judge each numbered phrase as a possible solution. Place the number of each solution which you consider *effective* in the column marked +. Place the number of each phrase which you consider *not effective* or *dangerous* in the column marked —. Each number should go in one of the columns, but no number may go in both.

Examples:

		+	—
1. A quick wood fire is desired. Which of the following would you advise a friend to pour on the smouldering wood? (+). Which would you not advise? (—). (1) kerosene, (2) water, (3) alcohol, (4) gasoline.	1.	1, 3	2, 4
2. On a camping trip, some sand is blown into the salt. The following suggestions are made to recover the much-needed salt. Which will be successful? (+). Unsuccessful? (—). (1) pour the mixture from a height allowing wind to blow sand particles away, (2) dissolve, filter and evaporate the mixture.	2.	2	1
3. Which of the following must be kept covered to prevent evaporation? (+). Which need not be kept covered? (—). (1) tincture of iodine, (2) gasoline, (3) table salt, (4) vinegar, (5) paraffin.	3.	1, 2, 4	3, 5

(Do the following in the same way.)

	+	—
1. A gas range smokes. If the following attempts at correction were made, which would be successful? (+). Unsuccessful? (—). (1) turn burner lower, (2) increase the amount of air in the mixture, (3) decrease the amount of air in the mixture.	1.	.....
2. A student is asked to dilute a concentrated acid. Which of the following procedures would be advisable? (+). Not advisable? (—). (1) Measure the required amounts of acid and water and pour the acid into the water, (2) measure the required amounts and pour the water into the acid.	2.	.....
3. A housewife wishes to bleach pieces of yellowed white silk and wool. Which of the following could she safely and effectively use? (+). Which not? (—). (1) alcohol, (2) lye, (3) hydrogen peroxide, (4) soda.	3.	.....
4. A piece of material is advertised as all wool. Which of the following substances would test the purity of a small sample of it? (+). Which would not? (—). (1) household ammonia, (2) vinegar, (3) alcohol, (4) lye, (5) carbolic acid.	4.	.....
5. Which of the following must be kept tightly covered to prevent rapid deterioration and consequent weakening? (+). Which merely evaporate? (—). (1) gasoline, (2) alcohol, (3) hydrogen peroxide, (4) household ammonia.	5.	.....
6. The so-called "sulphur water" owes its taste and odor partly to the presence of dissolved hydrogen sulphide. Which of the following methods would be effective in ridding a small amount of water of this disagreeable substance? (+). Which would not be effective? (—). (1) addition of lime, (2) boiling, (3) filtration through charcoal, (4), addition of alum, (5) filtration through sand.	6.	.....
7. In making a machine, a boy requires a disc of non-magnetic material. Which of the following may be used? (+). Which not? (—). (1) tin can, (2) sheet copper, (3) sheet		

brass, (4) nickel-plated brass washer, (5) galvanized sheet iron, (6) sheet zinc. 7. ....

8. If you spilled tincture of iodine on an unstarched white cloth, which of the following would completely remove the stain? (+). Which would not remove it completely? (—).

(1) soda, (2) alcohol, (3) vinegar, (4) water. 8. ....

9. A man working with a blow torch on a piece of metal wishes to remove some grease from it. Which of the following may be safely and successfully used? (+). Which not? (—).

(1) gasoline, (2) kerosene, (3) water, (4) carbon tetrachloride. 9. ....

10. For a small fast-revolving machine, which of the following could be effectively used as a lubricant? (+). Which not? (—).

(1) linseed oil, (2) kerosene, (3) vaseline, (4) gasoline. 10. ....

11. A candy recipe calls for a small amount of white corn syrup. Which of the following would produce the same effect? (+). Which would not? (—).

(1) vinegar, (2) salt, (3) honey, (4) cream of tartar, (5) soda, (6) lemon juice. 11. ....

12. A grass stain on a piece of white cloth may be removed. Which of the following solvents will remove it completely and safely? (+). Which not? (—).

(1) water, (2) alcohol, (3) gasoline. 12. ....

13. Cookbooks disagree as to the proper time to add salt in boiling vegetables. Three students discuss it. Their arguments are as follows. Which is correct? (+). Incorrect? (—).

(1) "If added before the water boils, it requires more heat."

(2) "If added before boiling it requires less heat."

(3) "It makes no difference for the amount of heat required to bring the water to boiling is the same whether added before or after." 13. ....

14. Silver nitrate is used in some types of laundry ink. If some were spilled on white cloth, which of the following would be effec-

tive in removing it and preventing the stain? (+). Which not? (—).

(1) alcohol, (2) ammonia, (3) lye. 14. ....

15. A man wishes to dilute some sulphuric acid. Which of the following containers could he safely and effectively use? (+). Which not? (—).

(1) aluminum pan, (2) iron kettle, (3) tin pan, (4) china bowl, (5) wooden bowl, (6) galvanized iron pail, (7) glass jar. 15. ....

16. The storage battery of a car contains sulphuric acid solution. After the car has been used for night driving a change takes place in the solution. Which of the following expresses the change? (+). Which does not? (—).

(1) more concentrated, (2) less concentrated, (3) more dense, (4) less dense. 16. ....

17. A drop of melted sulphur falls on the floor. Which of the following will completely remove it? (+). Which not? (—).

(1) water, (2) carbon disulphide, (3) ammonia, (4) alcohol. 17. ....

18. Calcium chloride may be sprinkled on a clay road to lay the dust. Some reasons for this are given below. Which is right? (+). Which wrong? (—).

(1) calcium chloride is heavy, (2) it reacts with the clay, (3) it absorbs moisture from air, (4) it prevents skidding. 18. ....

19. A burning candle drops wax on a table cloth. After scraping, a transparent stiff spot remains. Which of the following will safely remove it? (+). Which will not? (—).

(1) water, (2) gasoline, (3) lye, (4) ammonia. 19. ....

20. A student spills some acid on his hands. Which of the following will be effective to bring relief? (+). Which not? (—).

(1) germicide, (2) vinegar, (3) dilute ammonia, (4) soda. 20 ....

21. Mrs. Jones wishes to fumigate her home without removing tapestries and stuffed furniture. She is considering the following fumigants. Which would you advise? (+). Which not? (—).

(1) sulphur candle, (2) formaldehyde, (3) chlorine. 21. ....

22. Chlorine gas may be inhaled in small amounts to cure a cold. If too much is inhaled it is poisonous. Which of the following household substances give off vapors which would bring relief to a chlorine patient? (+). Which not? (—).

(1) ammonia, (2) alcohol, (3) boiling water 22. ....

PART TWO

The following paragraphs have been selected from popular science books. Read each selection carefully. Your understanding of the paragraph will be judged by your answers given in A, B, and C, following each selection.

Selection One *

"Empedocles—Empedocles (490-430 B. C.) combined the ideas of his predecessors and was apparently the first to speak of the 'four elements': earth, air, fire and water. These he supposed to act upon each other under the influence of love and hate (attraction and repulsion). He seems to have associated a genuine chemical sense with these expressions, for he is said to have stated that flesh and blood are made up of equal quantities of the four elements, whereas bones are made of one-half fire, one-fourth earth, and one-fourth water. Such a statement in itself goes far to show the irresponsible rashness and self-confidence with which philosophers of this age were wont to approach the discussion of things concerning which they knew nothing. Because coupled with the authority of great names this did untold harm in later centuries."

A. Below are six statements. Mark each one in the left margin using plus (+) for true, and minus (—) for false.

.... 1. According to Empedocles water is an element.

.... 2. Empedocles was a great experimenter.

.... 3. The law of definite proportions is foreshadowed in the preceding paragraph.

.... 4. Chemists today recognize water as an element.

.... 5. Empedocles' idea of the causes of chemical change is similar to our modern idea.

.... 6. Empedocles gave us our modern conception of elements.

B. In each word-series below draw a line through each word which is not consistent with (does not fit in with) the idea expressed by the first word of the series.

Examples:

1. American flag—red, [green] stars, blue, thirteen.
2. Summer—[Snow] flowers, grass, [sleighing].
(Do the others the same way.)
1. Element—complex, simple.

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* Selection 1. Moore, F. J. History of Chemistry, p. 4. McGraw-Hill Pub. Co., 1918. Reprinted with permission of publisher.

2. Attraction—uniting force, separating force.
3. Philosopher—statements based on experiment, statements based on authority.

Selection Two *

"The other ingredients of commercial glucose, the maltose and dextrin, have of course the same food value as the dextrose, since they are made over into dextrins in the process of digestion. Whether the glucose syrup is fit to eat depends, like everything else, on how it is made. If, as was formerly the case, sulfuric acid was used to effect the conversion of the starch or sulfurous acid to bleach the glucose and these acids were not altogether eliminated, the product might be unwholesome or worse. Some years ago in England there was a mysterious epidemic of arsenical poisoning among beer drinkers. On tracing it back it was found that the beer had been made from glucose which had been made from sulfuric acid which had been made from sulfur which had been made from a batch of iron pyrites which contained a little arsenic. The replacement of sulfuric acid by hydrochloric has done away with that danger and the glucose now produced is pure.

"The old recipe for home-made candy called for the addition of a little vinegar to the syrup to prevent 'graining.' The purpose of the acid was of course to invert part of the cane sugar to glucose so as to keep it from crystallizing out again. The professional candy maker now uses the corn glucose for that purpose, so if we accuse him of 'adulteration' on that ground, we must levy the same accusation against our grandmothers."

A. Mark each statement in the left margin using plus (+) for true and minus (—) for false.

.... 1. Glucose may be made from hydrochloric acid and starch.

.... 2. Glucose is a sugar.

.... 3. Glucose should not be used in candy manufacture because it is contrary to the food law regarding adulteration.

.... 4. The addition of a little acid in making candy insures fine texture.

.... 5. Arsenic is poisonous.

.... 6. Glucose crystals are finer than cane sugar crystals.

B. Below are two words each followed by other words some of which are consistent with the ideas expressed by the first words. In each series draw a line through each word which does not fit in with the idea expressed by the first word in that line.

1. Glucose—grainy, sweet.
2. Invert—make simpler, make more complex.

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* Selection 2. Slosson, E. E. Creative Chemistry, pp. 186, 187. The Century Co, 1919. Reprinted with permission of publisher.

Selection Three *

"Atomic structure is more completely illustrated by the familiar nitrogen of which we daily breathe about four times as much as we do of oxygen. Its nucleus contains seven more protons than electrons; in fact fourteen protons and seven electrons. Two of these apparently occupy positions on opposite sides like the satellites in the helium atom; and the remaining five at a greater distance from the nucleus are disposed as if on an imaginary sphere about the nuclear centre."

A. Draw a line under the sketch which best illustrates the description of the nitrogen atom given above.

B. A ten gallon vessel is full of air. How many gallons of oxygen are there? Of nitrogen?

Oxygen .....

Nitrogen .....

C. Below are four series of words. In each series draw a line through each word which does not fit in with the meaning expressed by the first word of that series.

1. nucleus—center, outside.
2. electron—positive, negative.
3. proton—positive, negative.
4. planetary—center, outside, round, square, positive, negative.

Selection Four *

"In 1777 he (Lavoisier) sums up his theory of combustion in the following four propositions:

1. In every combustion heat and light are evolved.
2. Bodies burn only in presence of air eminement pur (this was Lavoisier's first name for oxygen).
3. The latter is used up by combustion, and the gain in weight of the substance burned is equal to the loss of weight shown by the air.
4. By the process of combustion the combustible substance is usually changed to an acid; the metals, however, are calcined."

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* Selection 3. Caldwell, O. W. and Slosson, E. E. Science Remaking the World, p. 82. Doubleday, Page & Co., 1923. Reprinted with permission of publisher.

* Selection 4. Moore, F. J. History of Chemistry, p. 50. McGraw-Hill Publishing Co., 1918. Reprinted with permission of publisher.

A. Mark each of the following statements using plus (+) for true, and minus (—) for false.

.... 1. In view of modern chemical knowledge, proposition number one above is true.

.... 2. Proposition number three above is in keeping with modern chemical theory.

.... 3. Our theory of combustion has changed radically since 1777.

B. In each series below draw a line through each word which does not fit in with the idea expressed by the first word of the series.

1. Combustion—vacuum, heat, light, air.
2. Calcined—acids, bases, metals, oxygen.

STOP.

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VITA

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